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FROM

The New York State Water Supply Commission

STATE WATER SUPPLY COMMISSION

OF NEW YORK

STUDIES OF

Water Storage for Flood Prevention and Power Development

IN NEW YORK STATE

UNDER PUBLIC OWNERSHIP AND CONTROL

PROGRESS REPORT UNDER CHAPTER 569, LAWS OF 1907

TRANSMITTED TO THE GOVERNOR AND LEGISLATURE FEBRUARY 1, 1908

REPRINTED FROM THE THIRD ANNUAL REPORT OF THE STATE WATER SUPPLY COMMISSION, WITH REVISIONS SHOWING RESULTS OF ENGINEERING STUDIES TO MARCH 1, 1908

Compliments of

State Water Supply Commission

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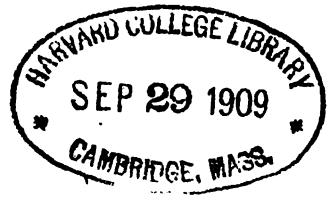

The Commission

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STATE WATER SUPPLY COMMISSION.

Members of Commission Appointed by the Governor.

HENRY H. PERSONS, President.....East Aurora
ERNST J. LEDERLE.....New York city
JOHN A. SLEICHER .....New York city
MILO M. ACKER.....Hornell
CHARLES DAVIS .....Saugerties

Officers.

WALTER McCULLOH, Consulting Engineer....Niagara Falls
CURTIS E. LAKEMAN, Secretary.....New York city

LETTER OF TRANSMITTAL.

ALBANY, *February* 1, 1908.

To the Governor and Legislature of the State of New York:

In compliance with the requirements of chapter 569 of the Laws of 1907, we have the honor to submit herewith the progress report of the State Water Supply Commission covering its investigations to date toward a plan for the progressive development of the water powers of the State under State ownership, control, and maintenance.

Very respectfully,

HENRY H. PERSONS, *President,*
ERNST J. LEDERLE,
JOHN A. SLEICHER,
MILO M. ACKER,
CHARLES DAVIS.

PROGRESS REPORT OF THE STATE WATER SUPPLY COMMISSION ON WATER POWER DEVELOPMENT.

To the Governor and Legislature of the State of New York:

The Legislature of New York by the passage of chapter 569 of the Laws of 1907, known as the Fuller bill, took an advanced stand upon the principle of State ownership and control of one of its greatest natural assets, namely, the vast water powers within its borders.

For the purpose of making a thorough investigation into the subject of State ownership of its water powers, and State control of the flood waters of the large streams, the Legislature appropriated the sum of $35,000 and directed the State Water Supply Commission "to collect information relating to the water powers of the State and to devise plans for the development of such water powers," and to report to the Governor and Legislature on or before February 1, 1908, the progress it had made with such investigation.

The plan and scope of the bill contemplates that the Commission, in making its final report, shall furnish to the State as complete and accurate information as would be required by a conservative business man who was looking only for profits before investing his fortune in a private enterprise. In building storage dams, the nature of the work is so intricate and requires so much technical knowledge of local conditions, namely, of drainage area, rainfall, stream flow, run-off, geological formation which can be learned only by deep borings, building material, lands to be flowed, rights to be acquired, flow lines to be established, coast line treatment, elevations, capacity of reservoir, dam foundation, height of dam, manner of drawing off water and the extent to which water may be drawn, the establishment of bench marks, etc., that a long period of time must necessarily be given and a large amount of

money expended in gaining the sufficient data to be included in any satisfactory final report.

As soon as the bill making these provisions became a law, July 12, 1907, this Commission immediately began the work it was directed to do.

Realizing the importance of a thorough investigation and the benefit which will result to the people by developing the water powers of the State under State ownership and by controlling the flood waters of the large rivers, the Commission determined to engage the services of one of the most eminent hydraulic engineers it could find to plan the investigation and direct the studies of the Commission. It secured the services of John R. Freeman for this purpose.

In company with this engineer, the Commission then made a personal inspection of the Sacandaga, Indian and Genesee rivers and their watersheds, for the purpose of determining upon which of these rivers it should make its first detailed studies. As the result of such preliminary examination, it was decided to make careful surveys of the Sacandaga river with the project in view of building a large storage dam at or near Conklingville, Saratoga Co., and also to make surveys and studies of the conditions on the Genesee river with a view to building a storage dam at or near Portage, so planned as not to interfere with the scenic beauty of Letchworth Park. The surveys, studies and investigations already made, prove the wisdom of these selections.

The State of New York is fortunate in having in its own mountains and highlands the sources of many large rivers which run their entire course within its territory, for fall as well as volume contributes to their value for power purposes.

Excluding Niagara and the St. Lawrence, the rivers of the State, with the proper storage of their flood waters, are capable of furnishing at least 1,000,000 horse power for industrial purposes. On account of the wide difference between the minimum and maximum flow of the streams, the minimum flow being the real test of the power value, at least 55 per cent. of their potential energy is lost to the owners of water rights and to the people of the State. It is clear therefore that 550,000 horse power of energy is annually allowed to run to waste because no well devised and com-

prehensive plan for the general and systematic development of water power has yet been undertaken by the State.

At a low estimate the advantage of water over steam power is at least $12 per horse power per year. The annual earning capacity of the wasted energy based on even so low an estimate is $6,600,000. Add to this the $1,000,000 per year of direct damage caused by floods, and the indirect damage which no one has yet been able to determine, but which is surely equal to the direct damage, and the value of an equalized flow during the summer months in the great rivers, which is not inconsiderable and the possibilities to be derived from proper treatment of the Niagara and St. Lawrence, and the aggregate will give some idea of the value to be obtained by the systematic development and increase of the water powers of the State.

The rivers of the State are and have been open to inspection by everyone. The locations of falls and power sites have long been known to individuals and it has not been difficult to acquire them. Meantime the possibilities of power development have been steadily growing and the advantages to be gained thereby have been constantly increasing. It is not strange therefore that far seeing men have purchased nearly all of the most desirable water power within the State, except such as may be situate along the boundary rivers.

Up to this time there has not been, and under present conditions there can not be such economical and general development of water power by private interests, as will include the storing of flood water on a scale at all commensurate with the advantages to be gained thereby. It is from this method that the greater amount of increase is to come. Moreover, the individual or corporation that invests money usually does so in the hope of immediate gain — the larger the immediate profits the more enthusiastic the promoter. There is therefore the temptation to cut out of the work everything that can be postponed or avoided, no matter how essential it may be to the future success of any well considered plan. The storing of flood waters will provide not only power development at the site of the dam, but will also increase the power of every user down the stream. The fear of improving the plant and power of a competitor might well restrain an owner

of water power from going further up stream and building a storage dam that would increase the value of his neighbor's plant as well as his own. It is also very difficult for several interests to combine in aid of such a project. Even though they should be willing to engage in a joint enterprise for such a purpose, there would be still the lack of power to condemn land for storage purposes for which recourse must be had to the law-making body.

The United States census of manufactures for 1905, Bulletin 88, shows that of the 1,647,969 horse power developed by water in the United States for manufacturing purposes, 446,134, or 27½ per cent. was used in the State of New York. This is more than twice as much as is used by its principal competitor, the State of Maine, and more than one-half as much as the total steam power for like purpose used in the State. The increase in water power in this State from 1900 to 1905 was over 100,000 horse power. This rapid increase in so short a period is, without doubt, one of the causes which has attracted the attention of economists to the value for the State's own benefit of this branch of its natural resources.

By means of storage dams constructed by the State at available points in order to hold back the flood waters of many of our large rivers, it is possible so to equalize their flow as to more than double the available horse power they now produce. Such improvement can be made to yield a revenue that will not only pay the cost of constructing and maintaining the dams, but that also will provide a large income for the State for all time.

The Commission believes that through the building by the State of storage dams, thus conserving water for power purposes, five distinct advantages will accrue:

(*a*) The construction of such dams will decrease the annual damage by flood waters.

(*b*) It will assure a larger minimum flow which will improve the sanitary conditions.

(*c*) It will provide a deeper channel for the Hudson thus improving navigation and insuring an abundance of water for the increasing needs of the canals.

(*d*) It will provide cheaper power for manufacturing purposes, and by stimulating various industries, furnish larger fields of em-

ployment, while insuring uninterrupted labor in already existing plants.

(*e*) It will provide a satisfactory annual income to the State.

Each of these points is in itself worthy of the careful investigation which the Legislature has directed to be made.

Controllable power is the vital force in our industrial development and one of the chief elements upon which civilization is based. Manufactories, transportation and artificial light are largely dependent upon it. The more complex our civilization, the more intricate our manufacturing enterprises, and the more important rapid transit becomes, the greater our dependence upon this force. There are two sources of power available — coal and falling water. Both require skill and money to turn their latent force into active energy. Coal once used is gone — but water however often utilized returns again — coal is growing less plentiful and more expensive — while water by the processes of nature keeps up its original force without additional cost.

It is universally conceded that the use of falling water for power purposes is much more economical than coal. As competition becomes more acute the value of water power over steam becomes greater. Cheap power must continue to be a vitally interesting subject to those who manufacture goods, provide transportation, and furnish light. The discoveries which permit the carrying of electrical currents a long distance have largely increased the value of falling water for power purposes. Such power must of necessity continue to grow in value as new opportunities for its use appear, and as the price of fuel advances.

This is a plain statement of an almost elementary truth with which all who stop to consider our industrial conditions are familiar. This economic condition is attracting attention to the possibilities of the greater use of falling water and constitutes a summons to those in authority to provide a way to save the lost energy that is annually allowed to run to waste in our rivers.

For years nature has presented the spectacle of wasted energy in water courses, and the action of the Governor and Legislature in directing so important a work as the conservation of this wasted power meets the hearty approval of all who have given the subject serious thought.

An enterprise of so important a nature on the part of the State will require new legislation. All new conditions require new laws to meet them. The Legislature and the officers and experts in charge of the undertaking can be trusted however to work out a just and equitable law that will meet every requirement necessary to enable the State to enter upon the project.

THE SACANDAGA DEVELOPMENT.

The studies, surveys and investigations made upon the Sacandaga reveal the following facts:

The Sacandaga river rises in the Adirondack mountains, its western branch in the south central part of Hamilton county, its eastern in the western part of Warren county, and it drains Lakes Pleasant, Piseco, Spy, Oxbow, Fawn, Elm, Sacandaga and others. The upper part of its water-shed is largely covered with forests, a great part of which are already owned by the State. These forests and lakes constitute of themselves natural reservoirs, and are so situated that with minimum effort their flood waters can be still more largely stored and made of practical use.

The Sacandaga river from its source to Conklingville is sixty-five miles long and has a drainage area of 1, 050 square miles. At Conklingville, the place selected for a dam site, the mountains come closely together and the river runs thence in a narrow valley to its confluence with the Hudson at Hadley.

Above the proposed dam, the valley to be flooded consists of farms and swamps. Thousands of acres are covered with a thick, brushy growth of alders of little value. A large part of the soil still farmed is not valuable for such purposes. Evidence of the poor quality of it is seen at a glance, and no amount of industry can turn these sterile flats into productive areas.

There are places where good farming lands are found, but in comparison with the great acreage of the valley these are few. Years ago when timber was abundant and tanneries flourished, prosperous villages grew and thrived. But of late the opportunities for manufacturing and farming are so few that, except in rare instances a general depopulation has taken place and this must continue. The mountains and hills forming the walls of the valley

are either rock or glacial sand drift; they are barren, steep, and contribute in no way to the thrift or prosperity of the occupants of the low lands. The river is subject to frequent spring and summer freshets which often flood large areas and destroy such crops as the land might otherwise have produced. It is a delightful country to ride through but a sterile one in which to make a living.

It is this valley that the Commission decided upon as one of the best in which to begin its investigations for the State. As soon as possible, therefore, after the bill authorizing these investigations became a law, the enterprise was organized under the direction of our engineer, and five surveying parties, including engineers, draughtsmen and drillers with boring outfits, properly equipped, took the field and began the work. They were directed to make careful and complete surveys, plot the area of the land to be overflowed,— take elevations to determine the flow line of the reservoir when full, and the point to which the water could be safely drawn down,— select a site for a dam and power house,— make borings to ascertain the location of rock foundation, locate a suitable place for a spill way,— gauge the river and streams tributary to it,— measure the capacity of the dam proposed and the amount of available flood water it would store for power purposes, and gather sufficient data on which to base conclusions and recommendations.

The Commission requested the engineer to answer the following questions:

(1) Can a suitable site for a large storage dam be located?

(2) How much water will such a dam store?

(3) How much water will the Sacandaga river at this point furnish for power purposes?

(4) What kind of property would be flooded by such a dam?

(5) The value of the property in the flooded area.

(6) How many horse power can be produced at the dam?

(7) How much would the proposed dam increase the present horse power development of each power plant down the stream?

(8) A plan of such a dam worked out in detail.

(9) A plan of a proposed power house worked out in detail.

(10) The total cost of such a dam and power house, not including land damages.

(11) The time required to complete such an enterprise.

(12) An estimate of the land damages.

On account of the short interval between the commencement of the work and the making of this progress report, the final answers to the 5th, 8th, 9th, 10th, 11th and 12th questions are not attempted at this date. These questions can be answered only after most careful estimates from accurate detailed plans that are yet to be made.

The answers to the 1st, 2d, 3d, 4th and 6th questions are such as to inspire confidence in the work contemplated and in the final results to be anticipated.

From the work already done it appears entirely probable that a safe and suitable site for a dam can be located at or near Conklingville, Saratoga county, that will cover an area of 40 square miles and store about 26 billion cubic feet of flood water; that the Sacandaga river thus dammed will furnish at this point a sufficient amount of water to produce 60,000 horse power of energy, which is greater than the aggregate water power of Lowell and Holyoke combined, or will increase the present available force at sites lower down the Hudson by 70,000 horse power for the six dry months of the year.

Such a dam will set the water back to the village of Northville, a distance of 30 miles, completely submerging the whole valley between these two points, including the villages of Munsonville and Huntsville, a part of the villages of Northville, Sacandaga Park, Northampton, Cranberry Creek, Vails Mills, Benedict, North Broadalbin, Batchellerville, Day Center and Mayville, and about 4 miles of the Fonda, Johnstown & Gloversville railroad. In building this dam the treatment of the shore line will be such as to make it an attractive sandy beach when the water is drawn down. This will be made possible by removing all timber, and by permitting the wave action in time to create conditions like those found on the margins of a natural lake, leaving nothing but clean sand or rock from the low to the high water line. Such a lake, extending from Conklingville up the river to the village of Northville, would add to the beauty and attractiveness of these

foot hills reaching up into the mountains. It would also furnish thousand of delightful camp sites upon a lake very much larger than most of those in the Adirondacks, and easier of access from large centers of population.

These facts have been derived from information carefully gathered by the Commission, and show that the increase of the available horse power for sites down the river, which can be obtained at this one storage dam by the broad and comprehensive plan of the Commission is 50 per cent. more than the total increase estimated by Mr. George W. Rafter in his "Hydrology of New York State," as possible for the entire Hudson river. It must be borne in mind, moreover, that the plan outlined contemplates building for the future. While seeking at this time to fully conserve the wasted energy of the Sacandaga river, at this point only, the Commission is not unmindful of the possibilities of additional storage dams on the head waters of the Hudson. As such energy has an actual value for power purposes, it is the design of the Commission in its final report on this subject, to respond in detail to all the requirements of chapter 569 of the Laws of 1907.

HADLEY RESERVOIR.

Surveys and test borings have been made at Hadley for the purpose of determining whether a storage dam can be built at this place across the Hudson which will economically increase the power development at each of the thirteen power sites lower down the river. The investigations have not proceeded far enough at this time to give the amount of flood waters that could be stored there for power development and flood protection. These investigations will be continued in the future work of the Commission.

GENESEE RIVER STUDIES.

The reports of our engineering corps and studies made therefrom and on the ground show what can be accomplished by storing the flood waters of the Genesee

The river takes its rise in the highlands of the Allegheny region in Pennsylvania, a few miles south of the New York State line. Entering New York, it runs across Allegany county, forms the boundary for some distance between Livingston

and Wyoming counties and flows in a general northeasterly direction through Livingston and Monroe counties, emptying at Charlotte into Lake Ontario. The total length of the river in New York is approximately 107 miles and its total fall from its entrance into this State to the surface of Lake Ontario is about 1,123 feet, giving an average fall in the State of 9.6 feet to the mile. The total catchment area of the river at Portage is 942 square miles.

From Portage, fifty miles above Rochester, down to Mount Morris the river flows for over twenty miles through a canyon in some places from 300 to 350 feet deep. At the head of this canyon are the Portage falls with a total descent, including rapids, of 330 feet in three miles. This fall is in three divisions known as the upper, middle and lower falls, with respective descents of 71, 107, and 70 feet, making an aggregate fall of 248 feet exclusive of intervening rapids.

From Mount Morris, at the foot of the canyon, the river passes through a broad level valley to Rochester, where there is another fall of 253 feet in 4½ miles. This fall with its power resources gave the first industrial stimulus to the development of Rochester, now numbering 182,000 inhabitants, and the third largest city of the State. Although the Genesee has a number of tributary streams, there are no existing power developments of consequence except at Mount Morris and at Rochester, where the total fall is utilized. The unexampled site at Portage is as yet untouched.

It is then to this great natural power site at Portage that the Commission has given its careful attention. The outlines of the proposed development include the building of a storage dam near the present Pennsylvania railroad bridge at Portageville, three-quarters of a mile above the upper falls and beyond the upper end of Letchworth Park. This dam, which would be of curved form, 1,200 feet long on the crest line, and 160 feet high above the foundation, would flood an area extending fifteen miles up the river and averaging a mile in width, forming a lake of fifteen square miles surface area, about as large as Canandaigua or Skaneateles lake. This reservoir would store 18,000,000,000 cubic feet of water, sufficient to provide a yearly average flow of

800 cubic feet per second for power purposes. The site for the power station would be near the hamlet of St. Helena, about five miles down the river as it flows, and below the limits of the Letchworth Park. In a line from the dam to the power house a tunnel 3 miles long and 18 feet in diameter would be built running in places 200 feet underground. The net working head at the power plant would be 500 feet, which would permit a gross development of 32,000 24-hour horse power, and increase by nearly 20,000 the actual 24-hour horse power now developed at Rochester; with use concentrated in working hours the number of horse power would be more than doubled. Such development on a basis of only $12.00 per 24-hour horse power per year would produce an annual revenue of $384,000 at the power station and $240,000 at Rochester. But other substantial benefits must also be considered, viz.: relief from annual damage by floods to the flat lands of the Genesee valley, to property in the city of Rochester, and also the great benefit that will accrue to that city by increasing the low water flow of the river, thereby removing the nuisance caused by the city sewers. This it is stated would obviate the necessity of the expenditure of a large sum of money by the city for a proposed trunk sewer. It is therefore clear that a storage dam of the capacity contemplated can be made to return a steady income to the State above all fixed charges.

The Commission has not considered any plan for the construction of a dam on the Genesee that would involve the slightest defacement of the scenic beauties of Letchworth Park. That the plan as proposed does not interfere with Letchworth Park must be evident, since both dam and power house are entirely outside its boundaries, and no part of the area proposed to be flooded is within the limits of the park.

The surveys and tests show that the logical and economical location for a dam is at or near the place selected by Mr. Rafter and described in the State Engineer's report of 1896, but as that location was partially within the boundary of Letchworth Park, instructions were given to our engineers to make studies for a dam site farther up the stream and outside of the park limits. Such a location has been found but on account of the width of the valley the cost of constructing a dam at the site selected

will be much greater than at the place advised by Mr. Rafter. The proposed storage reservoir would not destroy the scenic beauty of the falls by the diversion of water. Provision is made for several very large discharge pipes in the dam. By opening only one such outlet half way a flow of water would be provided which would exceed the present minimum natural flow over the falls.

A second line of possible criticism has been anticipated in connection with the claim which has been made that owing to geological formation, any dam of considerable size at Portage would be unsafe. The Commission therefore decided to investigate the subject and has had made a series of test borings to determine whether the formation of the hills confining the reservoir is such as would permanently and safely stand any strain or pressure against these natural boundaries by reason of building a dam at that point. These borings so far show that the hills consist of strata of impervious clay, hard-pan and sand, instead of quicksands as has been claimed. There is therefore no possible danger in building a dam at Portage.

In arriving at the conclusion that a storage dam capable of holding eighteen billion cubic feet of the flood waters of the Genesee river could be safely and profitably built at Portage, the Commission was not unmindful of the statement said to have been made by a noted scientist, the late Lord Kelvin, after a superficial examination, as he himself stated, of the maps and charts of the watershed, that "the proper method of utilizing the water power of the Genesee river is to construct small, comparatively cheap dams wherever on the water-shed pondage can be obtained giving a supply of several months." The well known reputation of the scientist quoted, and the wish to proceed upon accurate information, caused the Commission to make careful surveys and studies upon the upper waters of the Genesee to determine whether small dams in sufficient numbers could be economically built to store and furnish water in adequate quantities to justify the adoption of such a plan. The Commission finds that there are on the tributaries of the Genesee above Portage 12 possible dam and reservoir sites, that the combined storage capacity of these reservoirs would be only 3,362 million cubic feet, and would cost $1,200 per million cubic feet, or $4,031,100

for the 12 storage dams and reservoirs. This amount of storage is so small that it would be wholly inadequate for either flood protection or power purposes, and the cost out of all proportion to the benefits that could be derived therefrom. At Portage a dam and reservoir that will store five times as much water can be built and the cost per horse power will be only one-fourth part as great. The Commission is therefore compelled to report in favor of the larger plan as the more economical and wiser to adopt. For the reasons given under the head of "Sacandaga Investigation," the details of the plans for a dam and power house have not been completed nor the country fully surveyed for the purpose of locating the lands to be flooded and estimating the damage which will be done in the reservoir basin, or for locating the lands to be benefited by flood prevention and the value of such benefits. The studies thus far made convince the Commission that it is possible to develop throughout the State a comprehensive and systematic storage of flood waters, which can be made to produce for it a satisfactory and perpetual income.

RAQUETTE RIVER.

The Commission has made a personal inspection of available sites upon the Raquette river for dams and storage reservoirs.

The river has its source in the mountain streams and lakes of the Adirondacks, in the southern part of Hamilton county, at an elevation of about 1,700 feet. It has a drainage area above the outlet of Round Lake of 40 square miles; above Big Tupper Lake of 655 square miles, and above Piercefield of 690 square miles.

On account of the elevation of the water-shed above Piercefield, the annual rainfall in that locality is 48 inches, while the average rainfall throughout the State hardly exceeds 38 inches per year. This large rainfall upon more than 600 square miles of the upland water-shed increases the value of the Raquette river for water storage, and for power purposes.

There are many thousand acres of swamp lands besides a large area of lakes and ponds,—to wit: Tupper Lake, Long Lake, Round Lake, Little Tupper Lake, Blue Mountain Lake, Forked Lake and Raquette Lake,—that can be turned into storage reservoirs and the country thereby made much more attractive

and healthy than it is at the present time. A committee which studied the subject for the Water Storage Commission in 1902, reported that 20,000,000,000 cubic feet of water could be stored in this region at a cost of $50,000 for dams. The statement does not include land damages, and this estimate may be, and probably is, far too small. It is true, nevertheless, that there can be erected by the State, a series of dams forming reservoirs that would yield a large revenue to the State.

That the State could build storage reservoirs and not destroy the beauty of the mountains and forests, or their value for pleasure and health resorts, there can be no doubt. A visit to the camp of Hon. Timothy L. Woodruff on the upper waters of Moose river will convince the most skeptical that in his treatment of the boundary of the reservoir, made by building a dam about 400 feet long and 25 feet high, he has been able to turn the low and unsightly lands into an attractive and beautiful lake. With like treatment by the State and proper regulations prohibiting the drawing of the water below a fixed level, the State can turn the swamp and lowlands along the Raquette river into charming lakes, which will give the State a steady income above the expense of maintenance and interest charge; besides increasing the commercial prosperity of the portion of northern New York traversed by that river.

The details of developing power by means of storage reservoirs upon this river have not been worked out, but will be taken up in the future work of this Commission.

DELAWARE RIVER.

Since the commencement of the work of investigation under chapter 569 of the Laws of 1907, the attention of the Commission has been directed to the possibilities of power development on the Delaware river and the necessity of flood prevention thereon.

Communications and many petitions from local village officials and power users have been received, praying, in accordance with the provision of section 2 of the law, for the development of the water powers of this important stream, and asking that this water-shed be included in the studies of the Commission. Owing to the necessity of concentrating its preliminary efforts on the

two streams already selected for expository treatment, the Commission is able at this time to present only a cursory summary of the conditions along the Delaware. Such a first glance is proof, however, of the importance of the stream in any general scheme of power development and the necessity of carrying on more detailed investigations in that region.

The river rises at an altitude of 1,800 feet and with its two branches has a length of 105 miles in river flow in New York State and a drainage area therein of 2,570 square miles. It has an average fall within the State of seven feet to the mile and at Port Jervis, where it leaves New York, it exceeds in volume the Mohawk at its mouth and the Hudson at Schuylerville.

Since 1880 when there were 276 water powers in use on this river there has been a steady decrease in their number, which is keenly felt by property owners along the river. It is plain therefore that in any comprehensive plan of power development by the State the Delaware must be considered.

Plans have been proposed by interested persons for the storage and control of its waters by the erection of a series of dams which shall hold at least 26 billion cubic feet of water. These plans contemplate about 40 reservoirs, and also a series of river basins in the stream itself, each from 5 to 10 miles long. By so equalizing the river flow it is claimed that this project will secure safe and advantageous power development, and in addition will convert the region into a beautiful and attractive pleasure resort and greatly increase land values.

Without a careful survey and study of the river and its possibilities, the Commission cannot commit itself to any special plan of development, but the subject will be taken up and carefully considered in the future work of the Commission. It has under contemplation the advisability of having a conference upon the subject of water storage with the representatives of the States of New Jersey and Pennsylvania, in which States Commissions with powers similar to our own have been created.

A STATE POLICY OF WATER POWER DEVELOPMENT.

In the year 1885 the State of New York originated a policy of forest preservation, since which time interest in this subject has been steadily growing. Up to 1894, in addition to the acquisition of lands purchased by tax sale, in the Adirondack and Catskill mountains, only $25,000 had been expended by the State in purchasing forest lands, yet the acreage under State ownership had increased from 685,259 in 1885 to 713,806 in 1894. So great was the interest in forest preservation and water conservation, and so audacious the greed of private individuals and corporations to get control of these natural resources, that the Constitutional Convention of 1894 unanimously adopted the overture amending the Constitution of the State so as to preserve the lands purchased by the State in their wild condition. Since the adoption of the Constitutional provision prohibiting the cutting of timber and the destruction of the forests on State lands, the Legislature, by liberal appropriations amounting to $3,850,000, has made large additions to the State holdings in the Adirondack and Catskill mountains, increasing the total acreage to 1,518,450 on January 1, 1908.

These large sums have been appropriated for the benefit of the people of the State. Had this policy been adopted before private interest had acquired vast tracts of land in the mountains and devastated them by cutting and destroying the growing timber, millions of dollars would have been saved to the people.

There are at this time opportunities for the State to acquire at a minimum cost the necessary lands and rights for the construction of large storage dams for the control of flood waters, and for the development of water powers, which can be made to yield generous returns to the people, if built, developed and controlled by the State; but these same lands and rights will in a short time, like our forests, rapidly increase in price in the hands of private and corporate ownership. These valuable sites, like all natural resources, where nature has stored up immense treasure, grow more valuable each year as population becomes denser and the demand for their use increases.

We have only to look across our northern border to the Dominion of Canada to see how our mistakes in allowing private interests to acquire natural resources have been avoided by the statesmanship of the dominion government. Another lesson may

be learned from the policy of the Federal government in obtaining a revenue from the national forests.

A series of reports by the Hydro-Electric Power Commission of the Province of Ontario, show that a large saving to the users of heat, light and power can be obtained by utilizing water power instead of coal for these purposes. These reports to the dominion government were followed by the creation of a commission given authority among other things to expropriate the lands and water rights of power companies when in its opinion it would be for the interest of the people or of any community to do so. This statute of our neighbor is an evidence of its determination to preserve for the Canadian government these natural resources which will increase its annual income.

The increase in the revenue of the national government from the national forests was "more than 2,000 per cent. in the past two years, and one and one-half million dollars above the cost of administration." While we cannot hope that by the storage of flood waters the income of our State will increase with such rapid strides, it surely will be augmented at a rate that will astonish the average person and justify the estimates of economists who have given thoughtful attention to the subject. We are a growing people — the stream of water that will furnish a safe horse power of energy at a minimum cost has a definite value, and that value in a few years will increase. Shall we permit such sources of public profit to pass entirely from the control of the State?

Single interests which have studied the subject and become familiar with the value of water rights and the economy of water over steam, and who look only to private gain, may and probably will raise objections to any action on the part of the State toward the ownership of water power rights. It is clear, however, that individuals cannot economically develop the water power within this State and the opportunity for the State to do so should not be defeated by the determination of a few intent upon amassing fortunes and creating monopolies. Such purposes must yield to that broad policy which will most evenly and justly distribute the wealth of the State.

To acquire the dam sites and flowage rights on the large streams and begin the systematic building of storage dams at such places as will most quickly earn a revenue that will repay to the State the cost of acquiring such rights and of the necessary

construction seems to the Commission to be the plain duty of the State.

There are obstacles to such an enterprise, but they are not insurmountable.

In the area proposed to be flooded above the Sacandaga dam at Conklingville, there are about one hundred acres of forest preserve land. The execution of this project will therefore require an amendment to the State Constitution respecting the flooding of State lands. The same is true of other available locations for storage dam sites in the Adirondack mountains. In each instance the area of State land that would be flooded is small. An amendment to the Constitution that will permit the State to clear and flood State lands only where it shall be necessary to build storage dams in the interests of the people of the State and for a State revenue, these dams and reservoirs to be owned and controlled by the State, would be required to meet the exigencies of the situation. It is for the people of the State to decide, in view of all the facts, as to the expediency of such action.

Finally, the studies and investigations of this Commission have already been carried far enough to make it appear probable that it can, with the aid of the Legislature, construct a dam upon the Sacandaga river at or near Conklingville in Saratoga county and enter into contracts with reliable property owners on the Hudson river that will pay the interest on the bonds to cover cost of construction, create a sinking fund that will in a reasonable time retire such bonds and return a handsome annual income to the State. The revenue from this new source, it is confidently predicted, will steadily increase to an amount that will lead the people to regret the early policy of the State in allowing its great natural water power advantages to be acquired by private interests.

The report of our consulting engineer, John R. Freeman, and his assistants, accompanied with maps, plans and data, follows.

Respectfully submitted,

HENRY H. PERSONS, *President.*
CHARLES DAVIS,
JOHN A. SLEICHER,
ERNST J. LEDERLE,
MILO M. ACKER,

February 1, 1908. *State Water Supply Commission.*

APPENDICES.

REPORTS OF ENGINEERS.

STUDIES OF CERTAIN OPPORTUNITIES FOR WATER STORAGE FOR FLOOD PREVENTION AND POWER DEVELOPMENT

IN THE

STATE OF NEW YORK

UNDER PUBLIC OWNERSHIP AND CONTROL.

1. On the Sacandaga River near Its Confluence with the Hudson.
2. On the Genesee River near the Portage Falls.

BY

JOHN R. FREEMAN, HYDRAULIC ENGINEER.
HORACE ROPES, C. E., IN CHARGE SACANDAGA SURVEYS.
WALTER McCULLOH, C. E., IN CHARGE GENESEE SURVEYS.

APPENDIX A.

REPORT OF JOHN R. FREEMAN, CONSULTING ENGINEER.

January 31, 1908.

To the State Water Supply Commission:

Gentlemen.— On August 6, 1907, under your direction, I began engineering studies pursuant to chapter 569, acts of 1907, which became a law on July 12th and is popularly known as the Fuller bill.* This act requires a report of progress on or before February 1, 1908, and I have the honor to present one as follows:

My engagement was to supervise the organization and early progress of the work, and terminates on January 31st, the pressure of other work preventing my continuing. I will therefore report in much detail, in order that the reasons for the several studies begun may be made clear, and that the information obtained and the methods employed may be matters of record.

After a careful review of the specifications of the act, and a study of the topographic maps of the State and of sundry reports upon water power and water storage in the State of New York that have been published in previous years by the United States census, the United States Geological Survey, the New York Water Storage Commission and the State Engineer, it appeared to me best to concentrate the work upon the one or two large projects which after a review of sundry sites seemed to present the best opportunities for water power development under State control, rather than to spread the appropriation thinly over so broad a field of investigation that no conclusion could be reached on any one project.

One of these sites selected for investigation is located on the Sacandaga river near the point where it empties into the Hudson at Hadley, about forty-five miles northerly from Albany. This site promised the best opportunity of any found for the construc-

*See Appendix D Below.

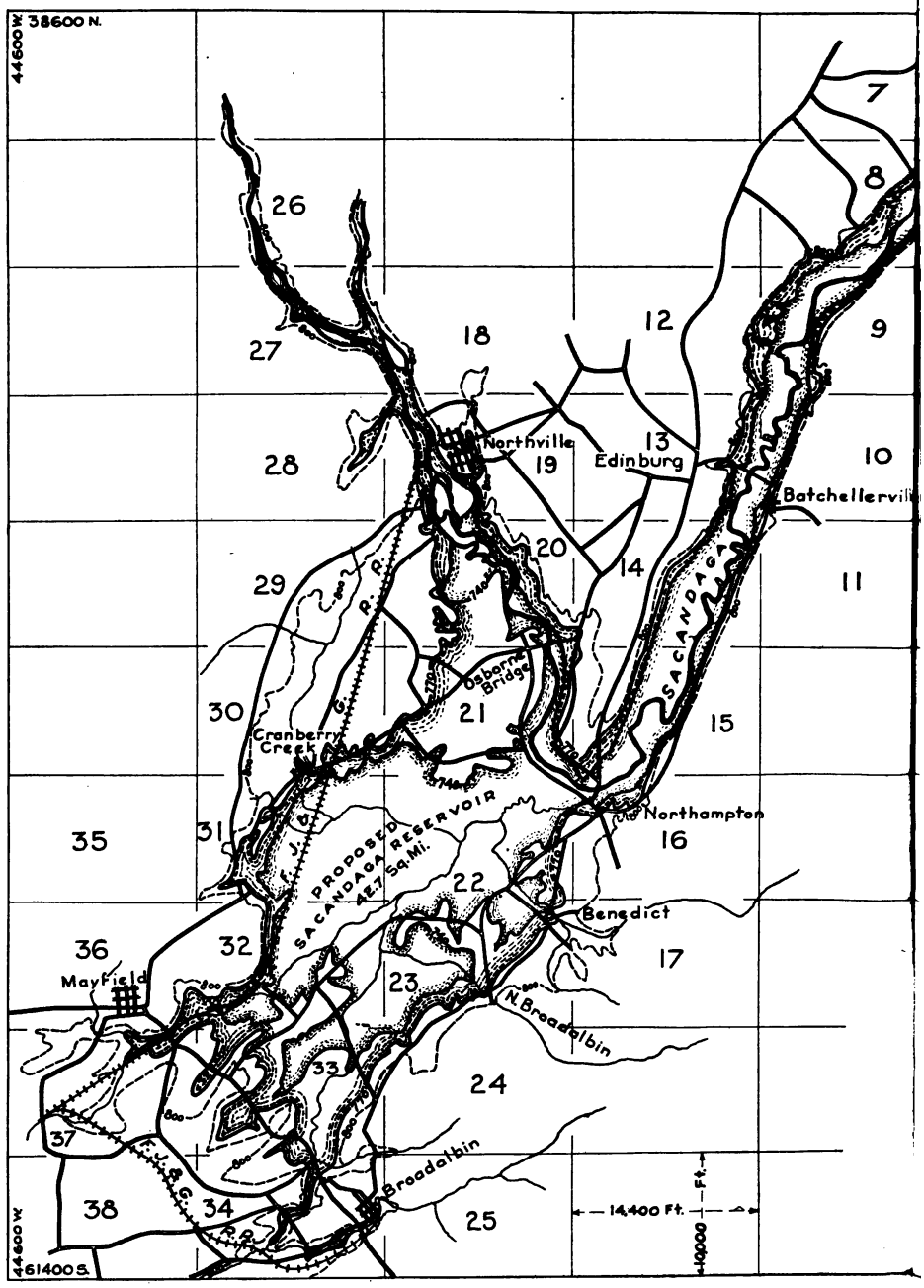
tion of a great storage reservoir for regulating the flow of the Hudson river for the benefit of the thirteen water power sites already established between Troy and Corinth, which have an aggregate fall of about three hundred and eighty feet. It would more than double their present power in time of drought and add upward of 70,000 horse power to the water power commercially available at these several sites already utilized upon the Hudson.

It also promised an opportunity for building later a power house in connection with its dam site, where the yield, if drawn at a constant uniform rate twenty-four hours per day and seven days in the week throughout the year, would give 25,000 to 30,000 horse power measured on the turbine shaft, or if distributed mainly in ordinary working hours, or under a 40 per cent. load factor, would deliver at Albany or elsewhere as needed within a radius of fifty miles, from 50,000 to 60,000 electrical horse power measured at the consumers' end, throughout even the dryest year.

The Sacandaga reservoir site also promised much more benefit than any other in the way of water supply for an enlarged Champlain canal, and for aiding in the increase of the mid-summer depth for navigation below Troy and for improving the quality of the water where taken for domestic purposes as far down as Poughkeepsie, by reason of the greater flow and the dilution in summer of the impurities that come from the sewers of the towns above.

Requests were soon received from the supervisors of Monroe county that a part of our work be devoted towards studying their problems of water storage for flood relief at Rochester and in the valley above it and of a power development in connection therewith, which should help carry the expense.

Four topographic survey parties and one party for precise bench levels were organized as rapidly as possible for the upper Hudson and Sacandaga studies, under the general supervision of Mr. Horace Ropes, an engineer of wide experience in hydraulic construction, but it proved impossible to get our survey parties well at work until about Oct. 1st, because of delays resulting from the scarcity of good men under the exceptional industrial activity then prevailing, the lack of instruments and an unusual amount of rainy weather.


38600 N.
44600 W.
44600 W.
4614005.
Northville
Edinburg
Batchellerville
Osborne Bridge
Cranberry Creek
Northampton
Benedict
Mayfield
N. Broadalbin
Broadalbin
SACANDAGA
PROPOSED SACANDAGA RESERVOIR 42.7 Sq.Mi.
14,400 Ft.
10000 Ft.
7
8
9
10
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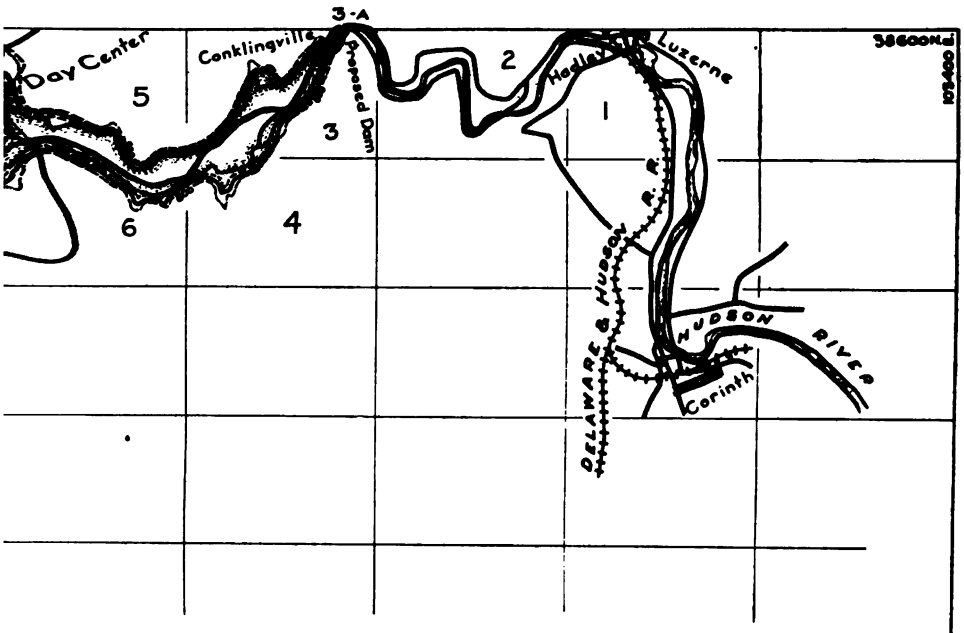

STATE WATER SUPPLY COMMISSION
SACANDAGA RESERVOIR
INDEX MAP
TO TOPOGRAPHIC SHEETS

John R. Freeman, C. E. January - 1908.

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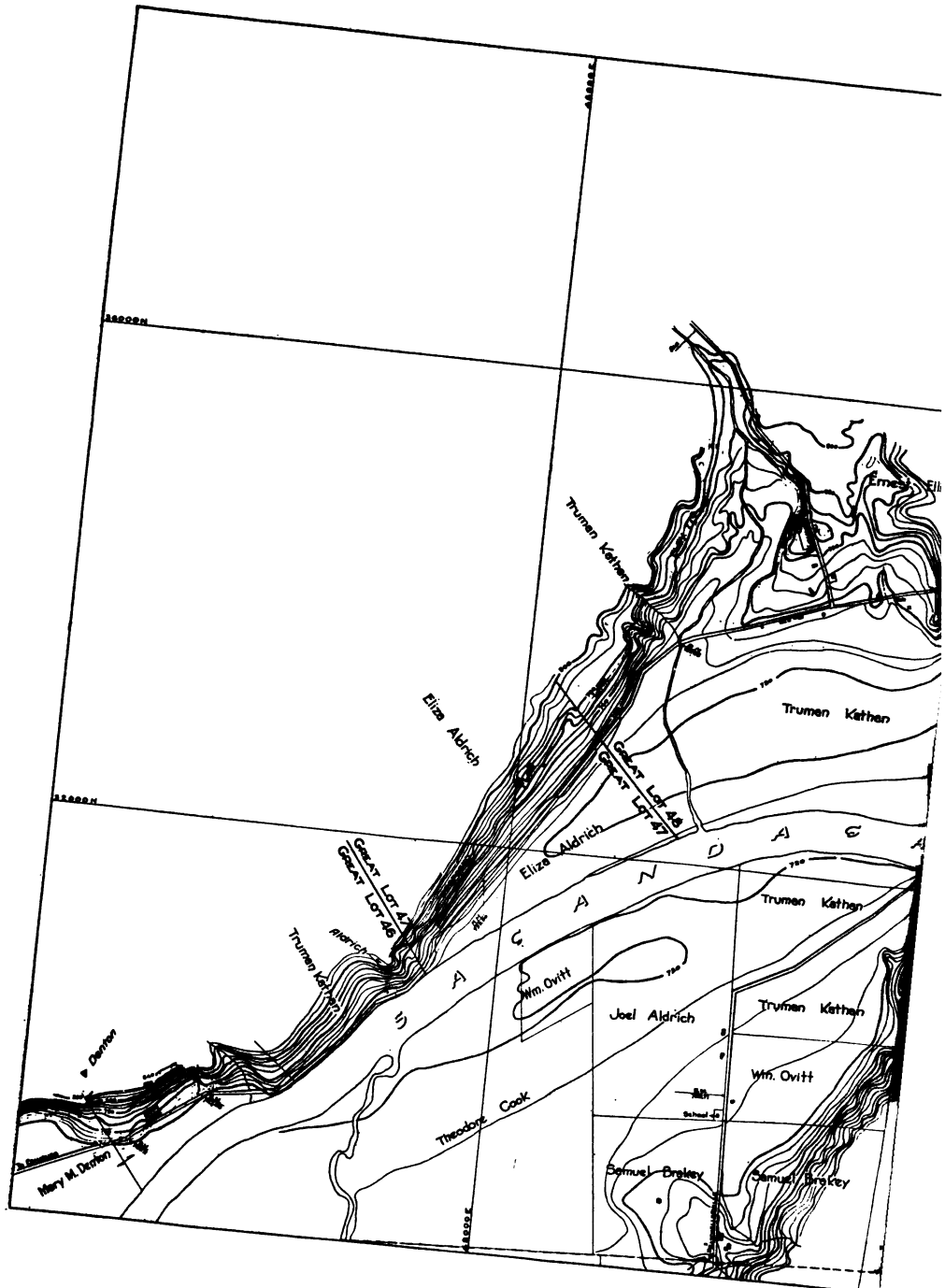
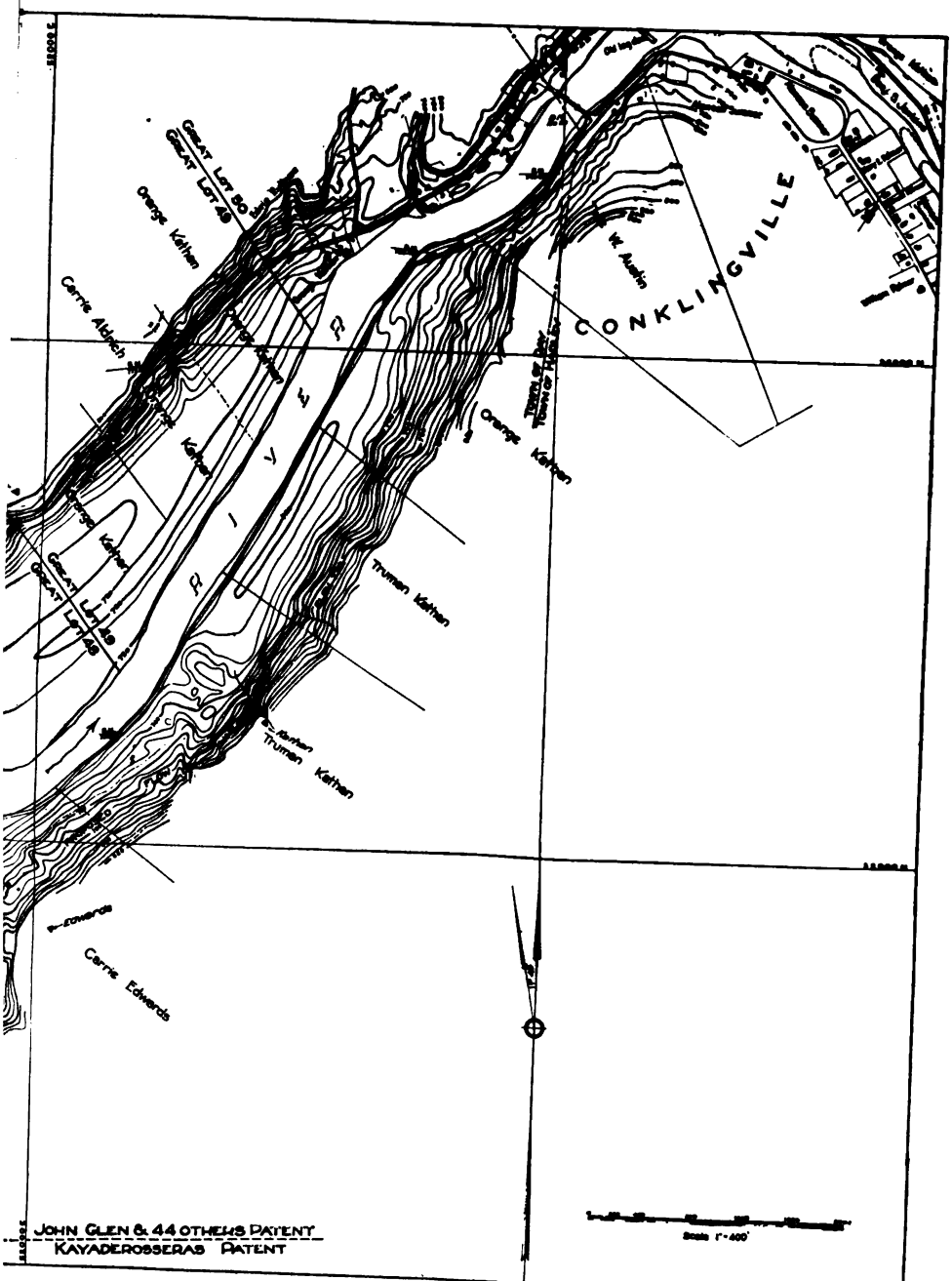
Scale of Feet.

0 1 5 10
Scale of Statute Miles.

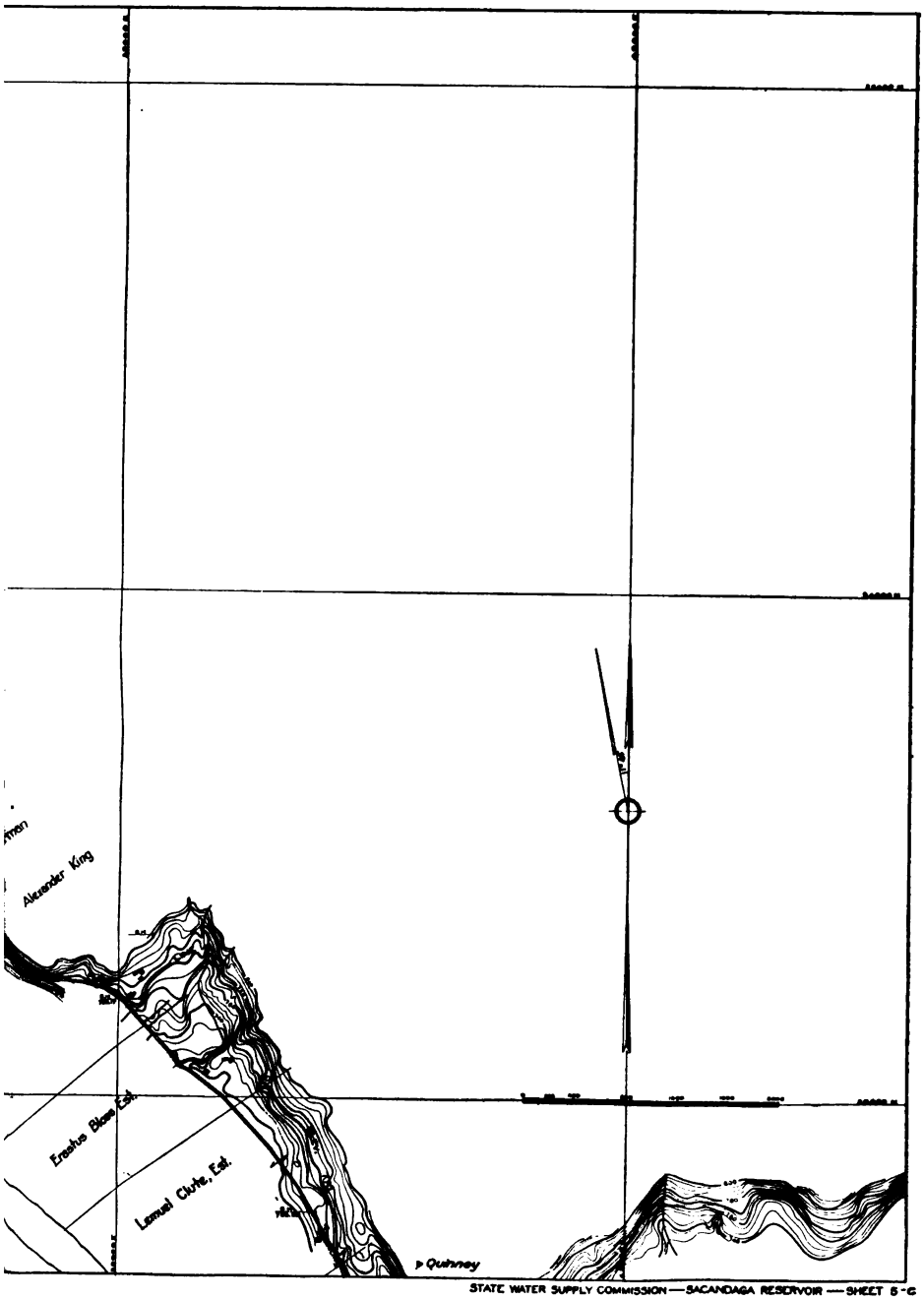
STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — INDEX MAP


Trumen Kathan
Elisa Aldrich
GREAT LOT 47
GREAT LOT 48
Trumen Kathan
Trumen Kathan
Elisa Aldrich
GREAT LOT 47
GREAT LOT 48
Trumen Kathan
Trumen Kathan
Wm. Ovitt
Joel Aldrich
Trumen Kathan
Wm. Ovitt
Theodore Cook
Samuel Brakey
Samuel Brakey
Mary M. Denton
D A G A
N
S A G A



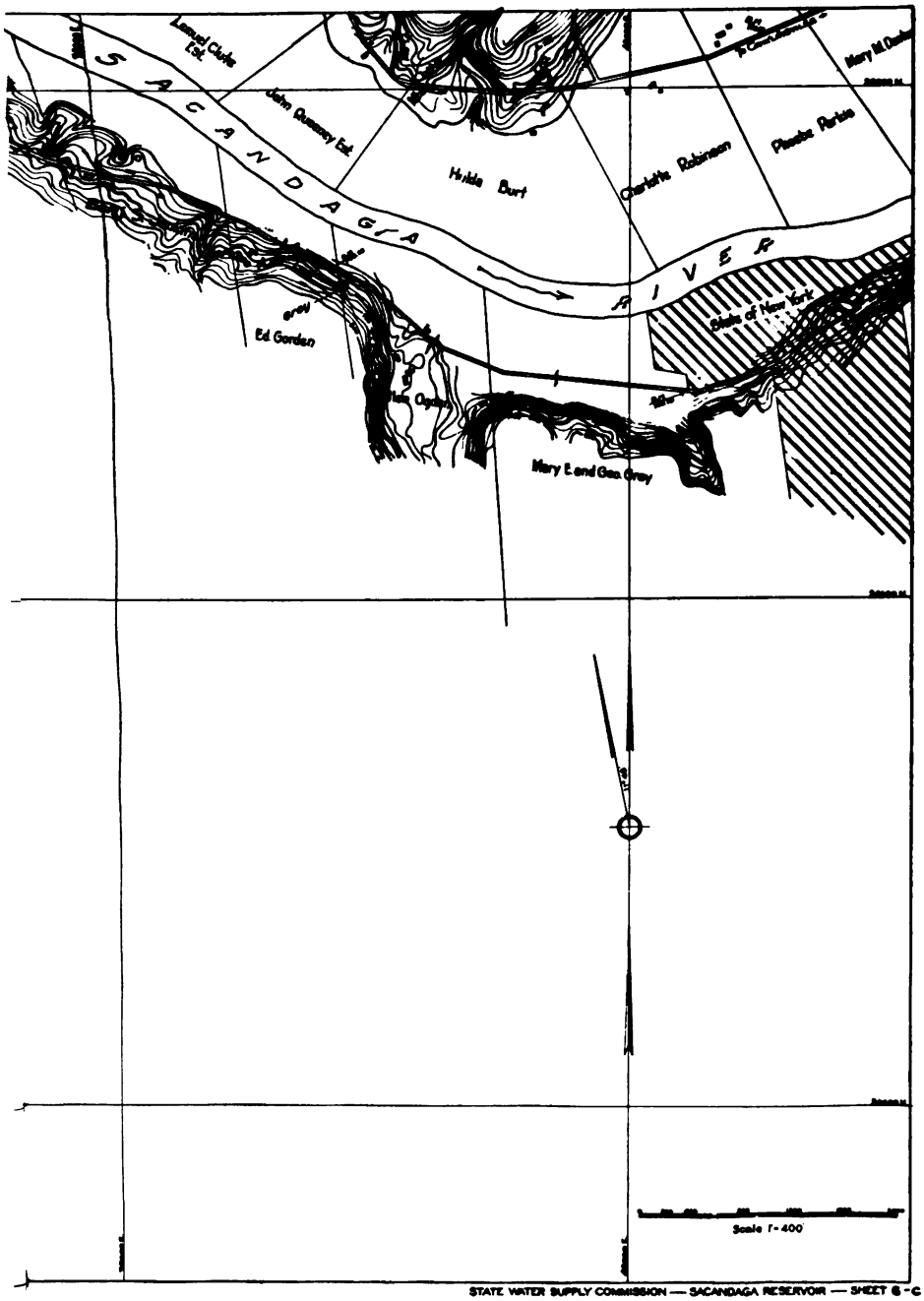
STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET B-2.

Marcellus
Van R. Rhodes
Arthur L. Paul
Van R. Rhodes
Eugene Giles
DAY
CENTER
Methodist Church
Margaret Van Avery
Clotilde Jenkins
Adelbert H. Paul
SACANDAGA
RIVER
Polly Robinson
Darling



STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 5-C

Margaret Van Avery
Emma Paul
Polly Robinson
Squire Houghton
Jerry Frasier
SACANDAGA
RIVER
Joshua LeBarron
Mr Edwards
Access N.
Access N.
300000 E.
300000 E.



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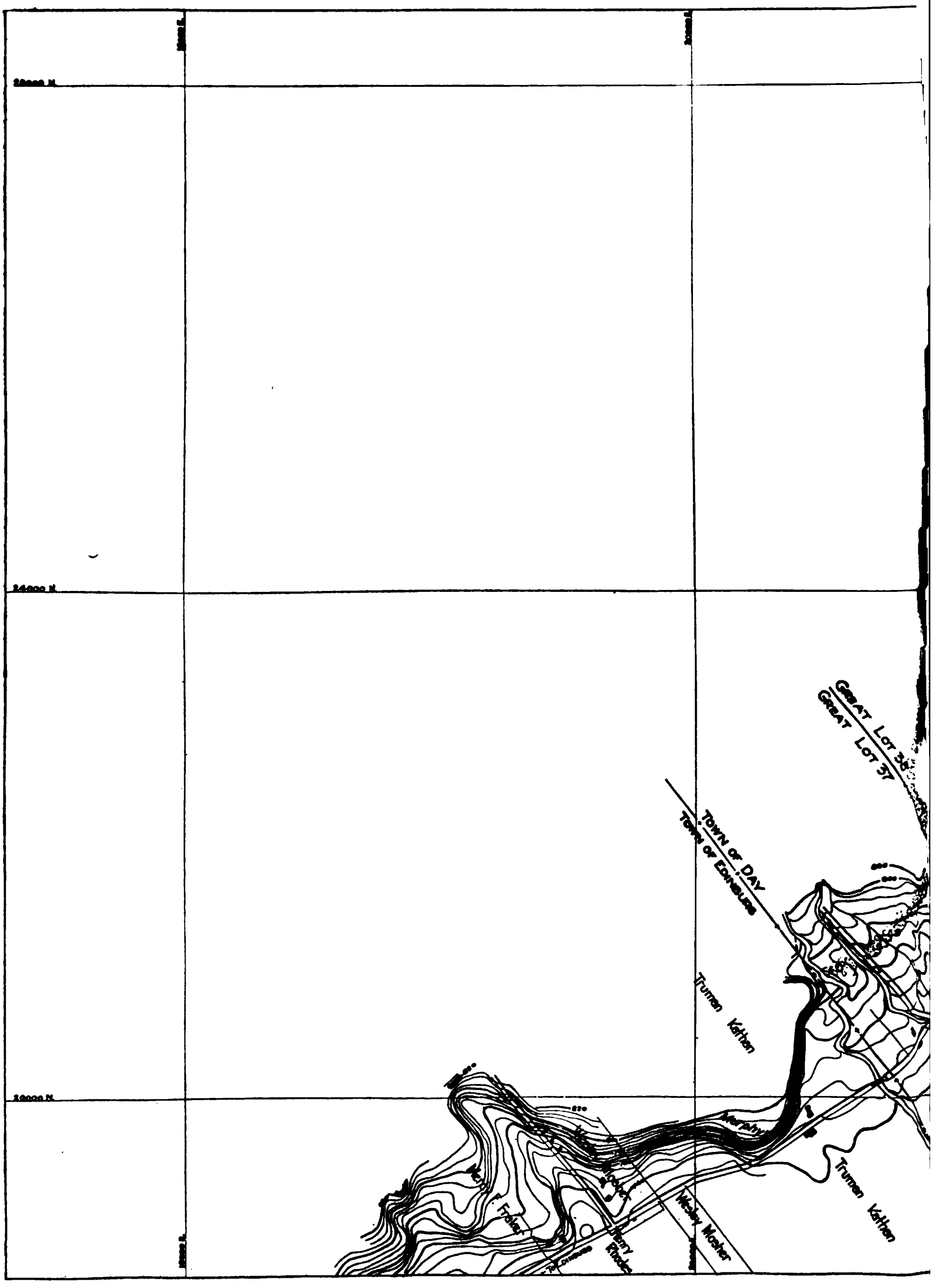
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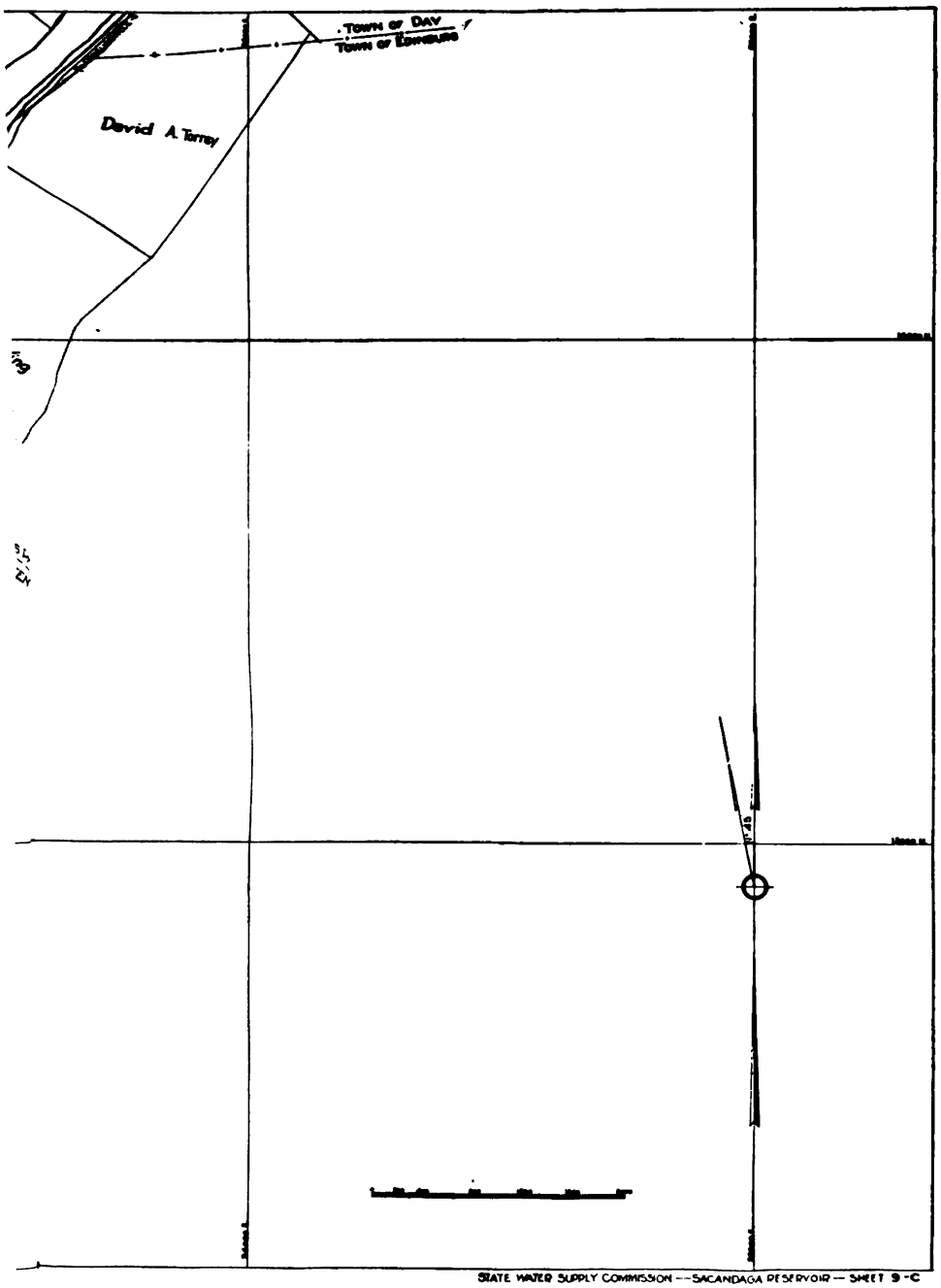
GREAT LOT 37
TOWN OF DAY
TOWN OF EDINBURG
Truman Kathan
Murphy
Wesley Mosher
Henry Rhodes
Truman Kathan

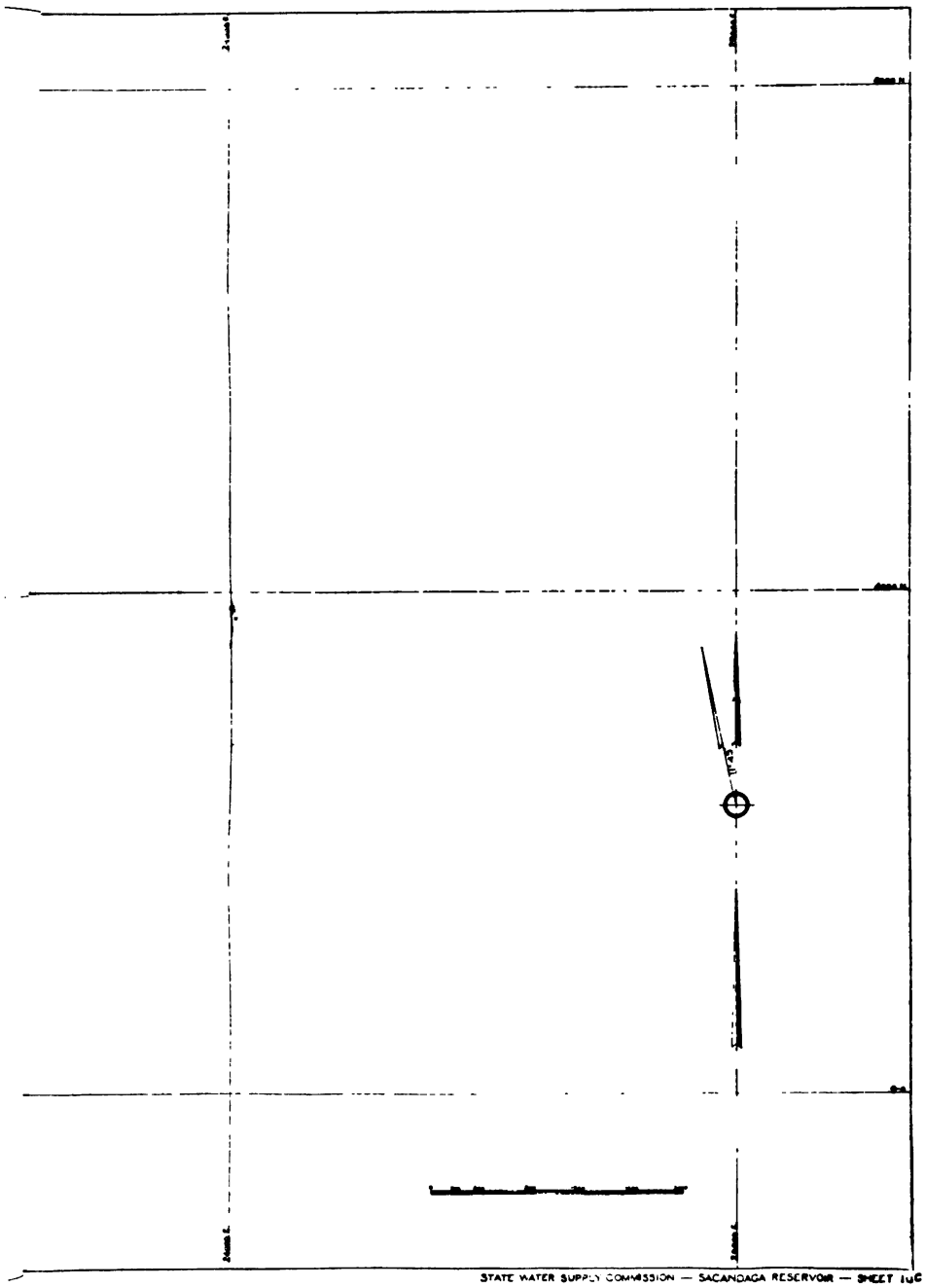
STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 8 - C

Truman Freeer
Mercy F. Frakes
Henry Rhodes
Wesley Mosher
Sarah Kellan
Henry Bovenkamp
Lucinda Johnson
Charlotte King
Aquilla Houghton
Joseph Allen
Erastus Johnson
Grant Freeer
David A. Farrell
Sherman Hibbard
Samuel Brownell
Daniel Y. Gorden
Alexander Armstrong
Delbert Noyes
Adelbert Gorden
Wm. Partridge
Daniel Y. Gorden
Henry Noyes
Mary F. Edwards
R. H. Lehman
44 OTHERS PA
OTHERS PATENT

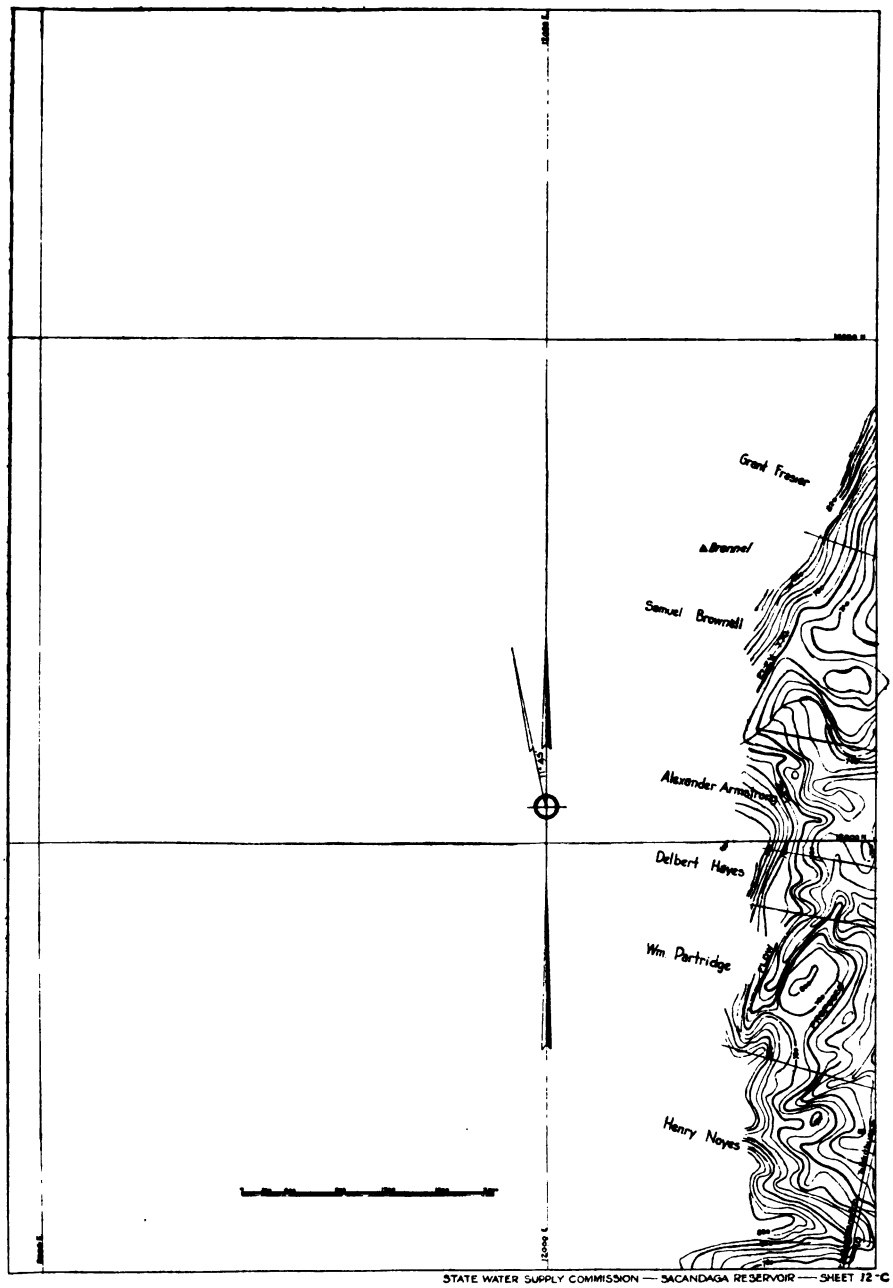


STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 9 -C

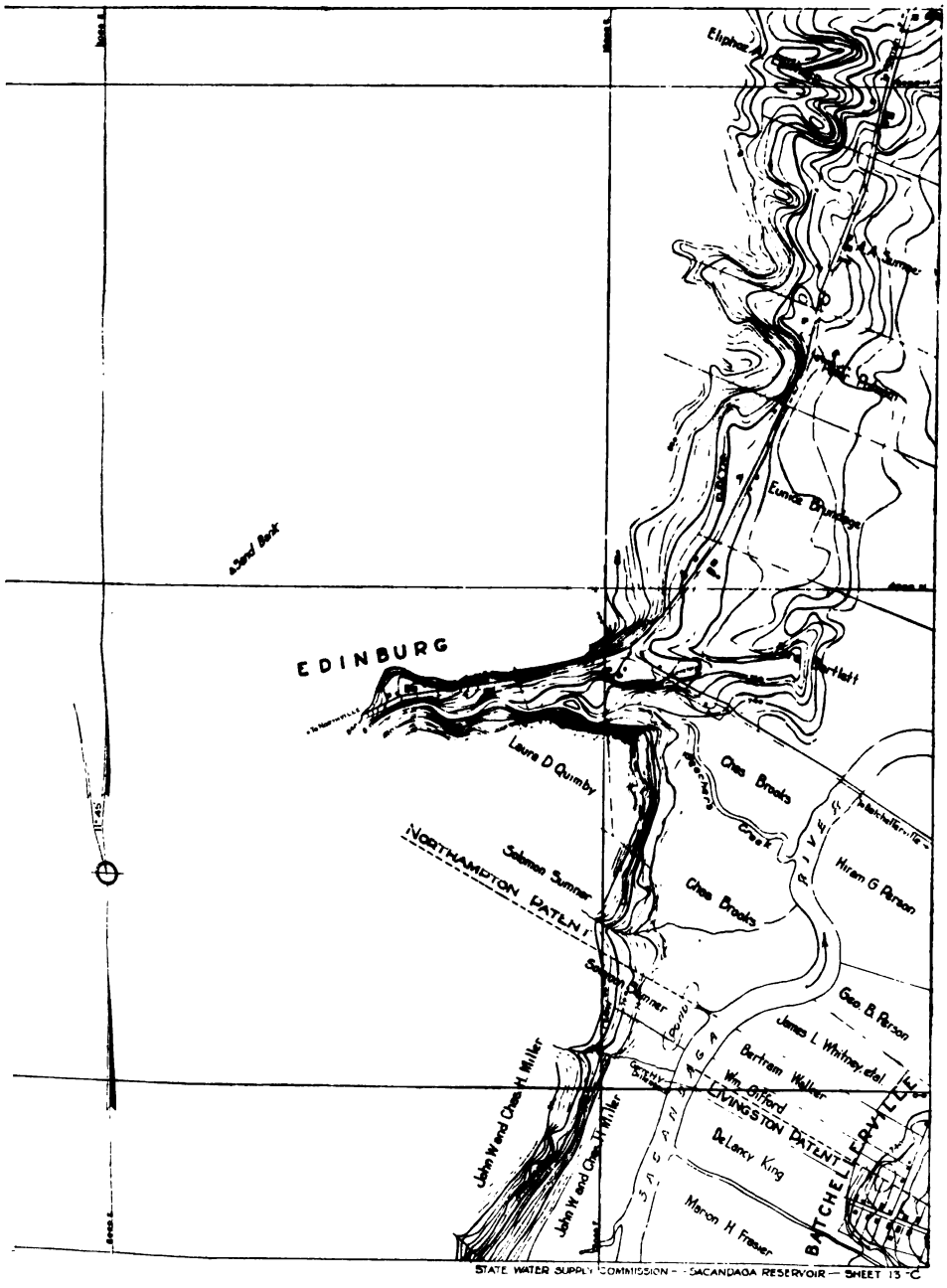
W H. Lehman
Mary F Edwards
Samuel F Norris
Elphaz D Ellitthorp
Asa Potter
A. A Sumner
Peter Putnam
former Channel
Nathan Edwards
Eunice Brundage
Peter S. Putnam
J. Filmore Robinson
James L D Whitney
Irving J. Vaughan
Simon Steel
Simon Steel
Hiram G Person
See E Person
ELLERVILLE



STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 106

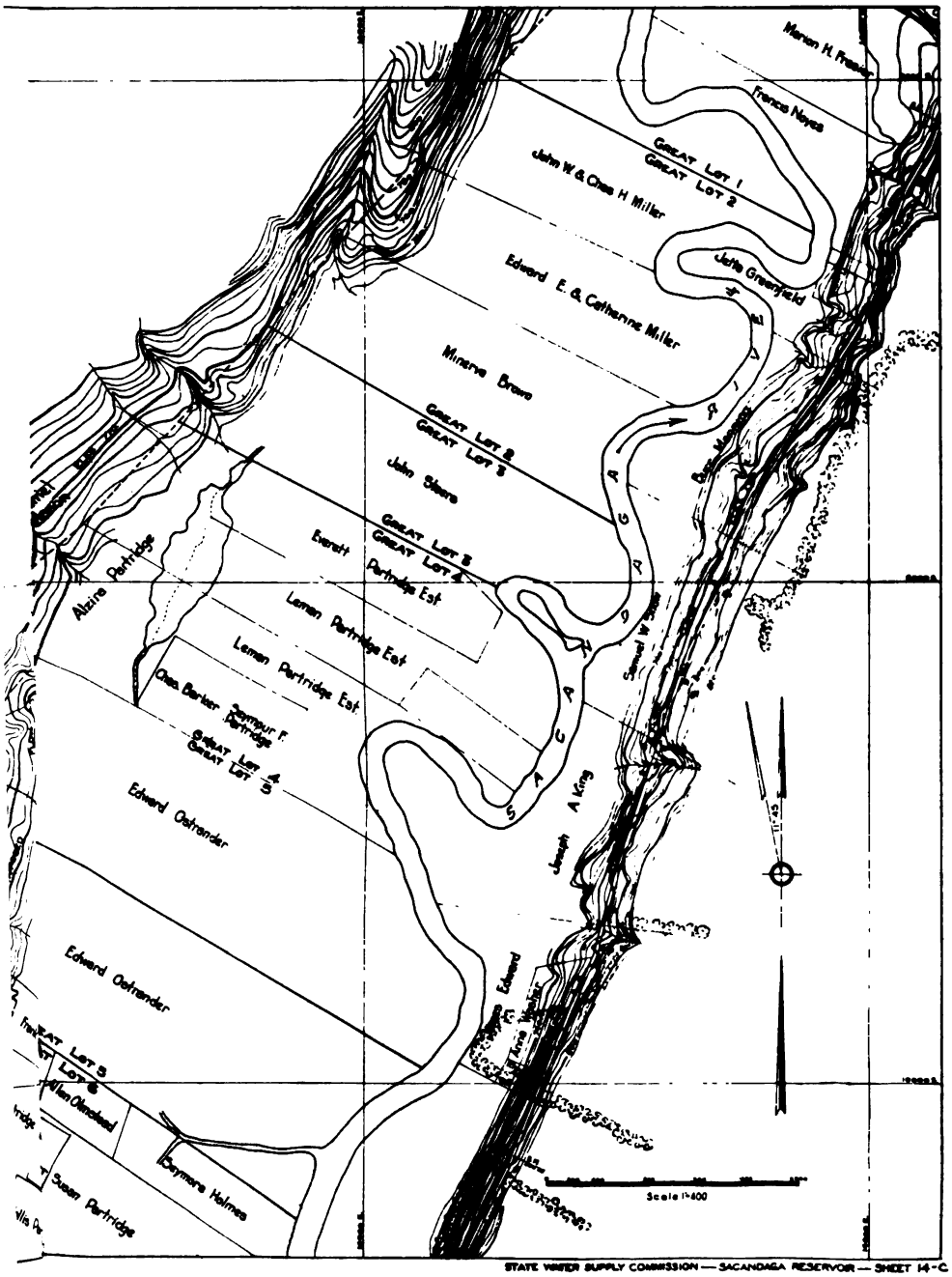


STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 12 -C



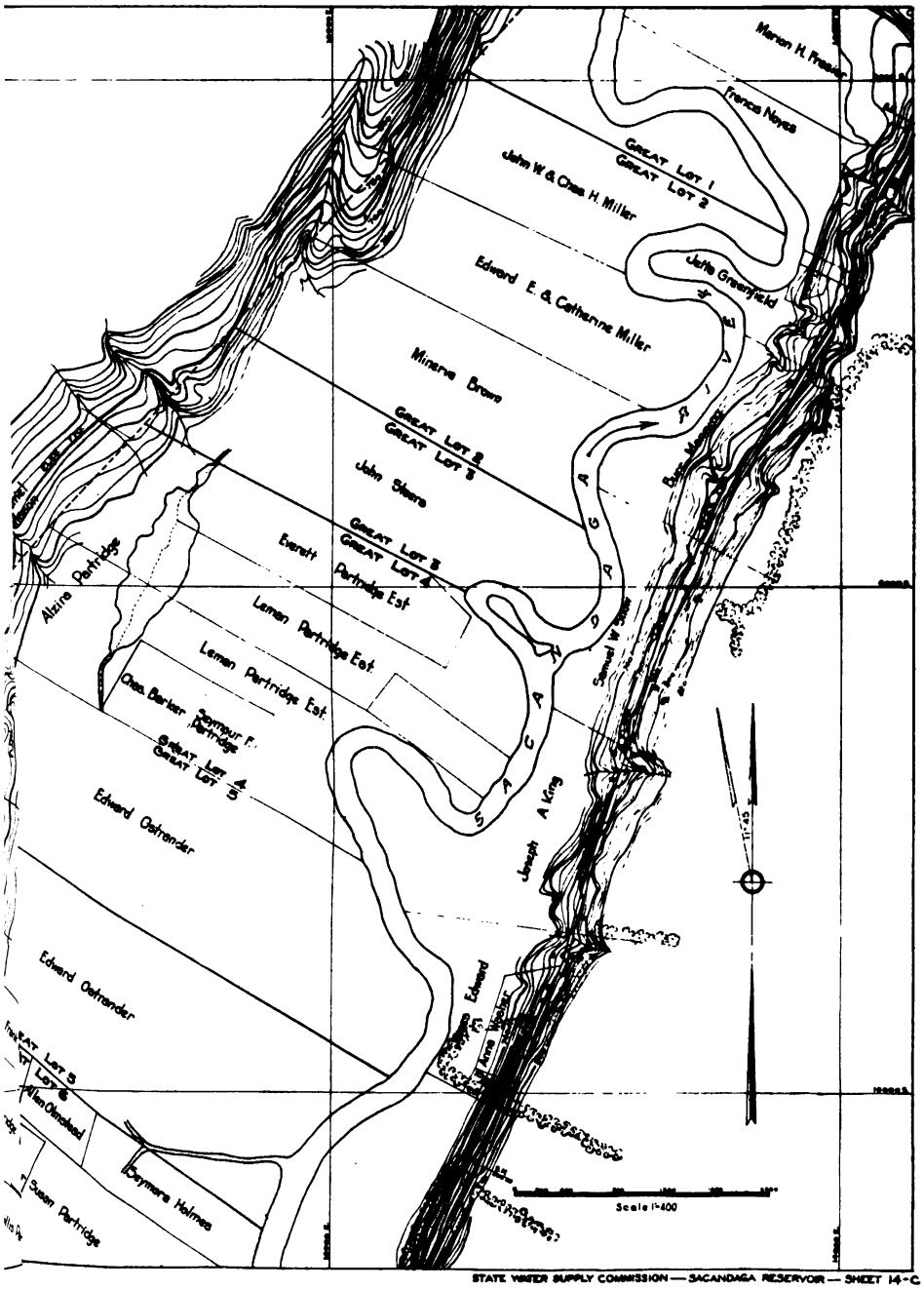
STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 13-C

LIVINGSTON GORE
NORTHAMPTON PATENT
Partridge
Hollis Park



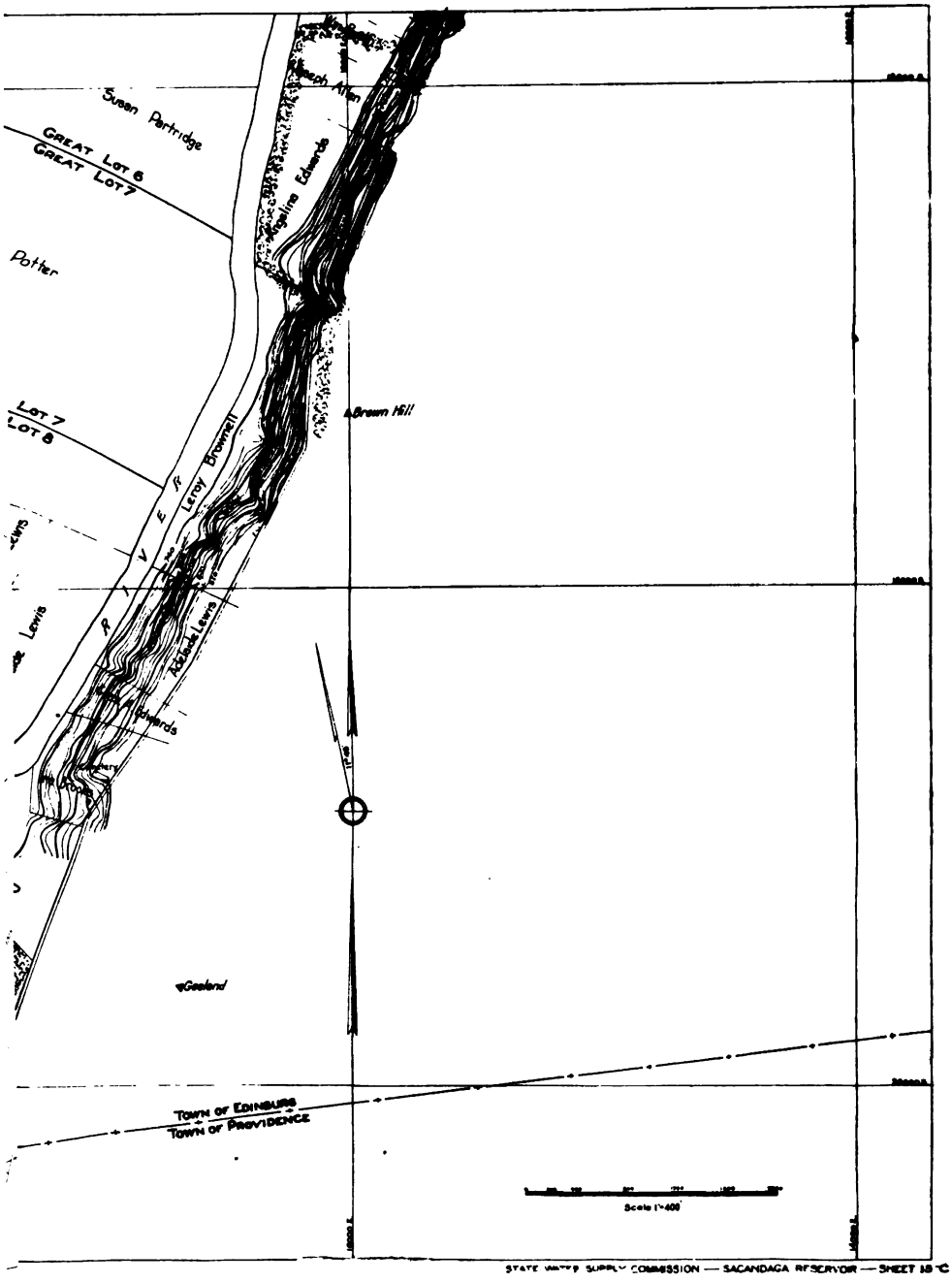
STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 14-C

LIVINGSTON GORE
NORTHAMPTON PATENT
Partridge
Annibal



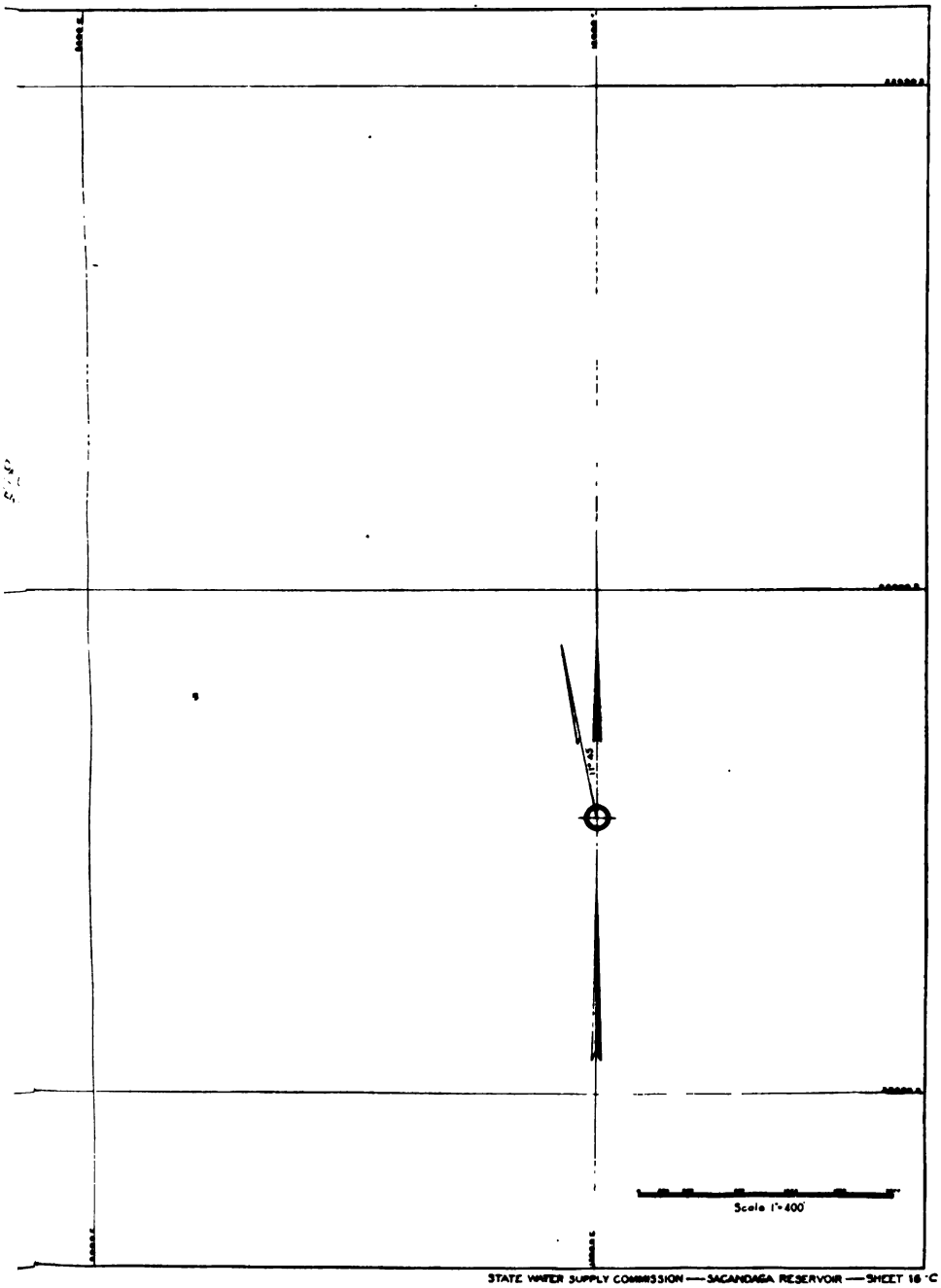
STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 14-C

FULTON COUNTY
SARATOGA COUNTY
TOWN OF NORTHAMPTON
Albert Brown
Tanner
Hiram Lewis
Hannah
Erskine Tanner
John Hough
Leroy Brownell
Abraham Burr Beecher
Wm H. Stark
Frank Gaeland
Frank Gaeland
Willis A Hayden
Mary M Fritcher
Mary M. Brown
Mary M. Brown
Albert Brown
Lucy J. Sinclair
Anna C Fitch
Nancy Playford
GREAT LOT 8
GREAT LOT 9
GREAT LOT 10
GREAT LOT 11
GREAT LOT 12
SARATOGA



STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 18 "C

SACANDAGA RIVER
Lucy J Sinclaire
Willis A. Hayden
Ellen E. Johnson
Elizabeth Closson
Lucy J. Sinclaire
John Brown
Creek
John Shaw
Robert Humphrey
NORTHAMPTON
NORTHAMPTON DATE
SACANDAGA PATENT
SARATOGA COUNTY
FULTON COUNTY
Fish House
MARSH



STATE WATER SUPPLY COMMISSION — SACANDAGA RESERVOIR — SHEET 16 -C

An additional topographic party was organized in October for the Genesee river studies under the general supervision of Mr. Walter McCulloh, the engineer permanently employed by your Board.

The four months intervening between Oct. 1st and Jan. 31st have obviously given insufficient time to accomplish work which might well occupy a year.

Work on test pits and borings at the dam sites, for proving the depth to ledge and the character of the substrata, have suffered from causes of delay which are not uncommon, and I am, therefore, unable to present final designs and estimates of cost with such fulness of detail as I would like, especially because of the test borings completed being much fewer than necessary.

Final and positive statements regarding the feasibility and cost of the two main projects studied are not warranted at this time, but it can at least be said that no insurmountable obstacle to either the Sacandaga dam site or the Portage dam site has yet been found, and that the outlook for both is very hopeful and abundantly warrants an expenditure for further study.

In brief, the work accomplished is as follows:

STREAM FLOW DIVISION.

1. Studies of all known records of the rainfall in the Adirondack region, and also upon the headwaters of the Genesee region, have been made with a view to determining the frequency and range of years of exceptionally small rainfall and with a view to learning if the storage must be planned to provide against greater droughts than those which have occurred in the period since accurate daily gagings of the river flow began.

Diagrams presenting these facts are submitted.

2. A tour of inspection of all known Adirondack rain-gage stations was made, and sketches made of surroundings of each gage, and an attempt to discover if some were less worthy of credence than others in making up the average.

Six additional rain-gages have been set in the Adirondack region in districts not well covered by the previous records, and continuous gagings of rain and snow-falls and daily maximum and minimum temperatures at these stations are being maintained.

Delay in receipt of instruments prevented beginning these measurements in season for study of the distribution of the remarkably abundant rainfall of last September. Records of this kind must be continued for several years before they become of much value.

3. Two series of comparisons have been begun between rain-gages of types used many years ago in making the early records and the standard type of rain-gage used to-day, with a view to learning if the early records are fairly comparable with the late records, or what correction should be added to make them so. One set of these observations is being carried on at Cornell University, the other set at the Clarkson Memorial Institute at Potsdam, N. Y. At least a year's record will be needed before any conclusive results will be obtained. Several years of comparison is desirable.

4. The average normal annual rainfall for both the upper Hudson and the Genesee regions has been determined and isohyetal maps (plates 10 and 19) prepared, and the facts that the rainfall is decidedly larger at the head waters of both streams, than for their drainage areas as a whole, have been fully established, and until in course of time additional rainfall records become available, this branch of the study is complete.

From this larger rainfall of the Sacandaga, the run-off per square mile is probably 15 per cent. larger than for whole of the Hudson drainage above Mechanicville, and the run-off of the Genesee dainage area above Portage, although less precisely determined, is probably at least 12 per cent. larger per square mile than for the entire Genesee above Rochester.

5. A review and comparison of all published gagings of the flow of the several tributaries of the upper Hudson has been made.

6. A series of daily river gagings on the more important tributaries of the Hudson, viz.— at three points on the Sacandaga, at two points on the upper Hudson and at one point on the Schroon, has been begun in co-operation with the United States Geological Survey, the observers being paid from the funds provided under the Fuller bill.

These observations have beeen carried on continuously since about Sept. 1st and fortunately were begun just before the close

of a remarkably severe drought. They are for the purpose of showing the relative yield per square mile of the different tributaries and for comparison with the long established gagings of the flow of the whole river at Mechanicville.

7. New measurements have been made of the present diversion of water into the Champlain canal, and the compensation necessary on this account for correcting the records of the Hudson river's daily flow past the gaging stations at Fort Edward and Mechanicville has been determined and a corrected record prepared.

Records of the storage control of Indian lake have been worked up as well as the crude data available will permit, in order to show just what effect the large dam built here in 1899 with the co-operation of the State, has had in reinforcing the low water flow of the Hudson.

8. The amount of storage required for permanently regulating flow of the upper Hudson river in general and that of the Sacandaga tributary in particular, has been estimated in great detail, so that the yield from the proposed storage reservoir and its effect in adding to the low water flow of the Hudson can now be predicted with all the precision and certainty necessary for water power studies.

Diagrams have been completed showing the volume of the Sacandaga flow that can be safely relied upon for power in the severest drought, corresponding to various given amounts of storage; also diagrams showing the reservoir depletion that would have occurred year by year with the proposed rate of draft and the proposed volume of storage.

SACANDAGA SURVEY DIVISION.

9. A general system of triangulation over the entire territory was established, and the several partial surveys have all been reduced to one rectangular co-ordinate system, and mapped in accordance therewith. The geodetic connection of this co-ordinate system to the primary points of the State survey or to the precise latitude and longitude have not yet been made, because of requir-

ing a resetting of signals on distant summits and because of intermediate triangulation being necessary to get up out of the valley so as to see them. The effort has been to leave maps and records in such shape that any future engineer can pick up station points and extend or amplify the work.

10. Contour maps on a scale of 100 feet to the inch have been prepared for each one of the thirteen villages, large and small, near to or within the site of the proposed great storage reservoir.*

These maps show the location of substantially every house in each village, and how near it would be approached by the water's edge with flow lines of various elevations. The purposes of these maps are to show the highest admissible elevation of flow line for the great reservoir, and to give an accurate idea of the disturbance or damage that would be caused.

11. General topographic maps on a scale of 400 feet to the inch, with contour interval of five feet, have been prepared, embracing substantially the entire territory of about fifty square miles comprised by the proposed reservoir and its margins. These sheets, of standard size, 26 x 38 inches, were pantographed down from our survey plottings made on large sheets on a scale of 100 feet to the inch.

For that portion of the reservoir site lying below an elevation of 740 feet above sea, we obtained much aid in our map making from a very good set of land boundary maps with elevations, made by the Hudson River Power Company, of which maps, the president of the company, Mr. Eugene M. Ashley, kindly permitted us to make copies.

Time has failed for the completion of the full topographic work. Several gaps are left in the survey around the reservoir margin in localities of little importance, or where thick woods interfered with rapid progress; but out of more than 100 miles of margin probably less than ten miles is unfinished, and a reconnoissance has been made in these gaps sufficient to show the lay of the land.

12. The volumes of the proposed Sacandaga reservoir to various proposed heights of flow line have been determined from the

* Copies of these maps are inserted at page 156 reduced.

contour maps just described, by means of planimeter, and are presented in a diagram on plate 3 opposite page 112.

13. Four alternative sites for the proposed dam near Conklingville were surveyed and plotted on scale 100 feet to the inch, in order that comparative estimates of cost might be made and the best one selected.

At what now appears the best site the river bed is 700 feet above sea level and the dam proposed would raise the water about fifty-six feet above its present level at Conklingville bridge.

14. A line of topographic survey has been made showing the elevations and surface characteristics and shaft sites over the tunnel line, nearly three miles in length, between the proposed dam and the proposed power house site. Time and means have not permitted the making of borings and test pits along this line, but no serious obstacle to construction has appeared.

15. A topographic map of the proposed power house site has been prepared showing various alternative locations and ground available for a surge tank at lower end of tunnel line.

16. Surveys with topography and borings along the proposed tailrace location about one mile in length following the river have been made, with a view to the feasibility of obtaining at a single power house the entire fall between the proposed Sacandaga reservoir and the ordinary level of the Hudson river at the confluence of the Sacandaga at Hadley.

With a flow line established at an elevation of 770 feet above sea, the Hudson being at 548, the ordinary levels in pond and tailrace would give a gross fall of about 215 feet and a net working fall at medium loads of about 200 feet, or perhaps of only 170 feet if the deep tailrace proposed proves too expensive.

17. Five "wash-drill" borings have been made in prospecting for the best dam site at Conklingville, and although the deepest of these holes bored extended about 175 feet below the present level of the river, no bed rock under the present river bed was reached. Many more borings are needed to develop with absolute certainty the character of the substrata at all parts of the dam site and to define the precise contour of the ledge at the spillway site.

The diamond drill borings begun on the up-stream dam site on the side of the river nearest to the ledge outcrop have suffered from a series of accidents, and the one successful hole now has its casing down about 100 feet below the river level without reaching ledge.

The substratum that fills the deep preglacial gorge as revealed by all these borings is an extremely fine impervious sand, and of a character, so far as shown by the borings already made, that will serve with entire prudence and safety for the foundation of the type and height of dam proposed for this site.

The type of dam which promises best among those now being studied is an extremely thick earth dam to be formed probably by hydraulic sluicing, filling the present channel twenty-five feet above the full reservoir level, and is combined with a new spillway channel over natural ledge off to one side of the present river channel.

During construction, it is proposed to take the river flow through a twenty foot tunnel in the ledge and to safeguard the partially completed earth work by crib dam such that in the chance of a serious freshet while work is in progress, no catastrophe could occur.

18. Alternative studies have been made along the ledge outcrop on two sides of the river for the location of a flood spillway, or by-wash, suitable for carrying the entire flow of the river in a flood much greater than any known to have ever occurred, and while many additional borings would be needed before preparation of final plans, the present outlook is that such a spillway over ledge is feasible. Provisional plans for the dam, its spillway and sluices are presented.

19. For most of the houses within the flow limits of the projected Sacandaga Reservoir, an outline measurement and a brief description and estimate of its fair value has been made, and such information as was available in the rapid progress of the surveys has been obtained bearing on the present fair market value of the lands to be flowed. From this brief and somewhat incomplete data, an estimate of the real estate damages has been made up.

Included in this is an addition of 50 per cent. to the probable fair market value to cover legal expenses, liberal settlements and contingencies.

In general this land in the territory to be flowed is not fertile, the houses are not very valuable and the village of Conklingville has been decadent since the loss of its industries, a tannery and a wooden ware factory; the last of which stopped some five years or more ago and is in a state of decay.

It is of interest that a large part of this property, lying below contour, 750, was bonded for purchase by the Hudson River Power interests within the past two or three years, but a part of these bonds, which involved no substantial cash payment, have expired recently and have not been renewed.

20. A partial survey and study has been made for the relocation of a portion of the railroad which runs from Gloversville to Sacandaga Park near Cranberry creek.

21. On the Hudson river between Hadley and Luzerne, a dam site for the storage reservoir mentioned by Mr. Rafter in the Hudson river storage studies of 1895, has been partially surveyed and the surrounding topography measured, sufficiently to show what houses would be affected and sufficiently to give an approximate idea of the capacity of the proposed reservoir. Extremely cold weather and deep snow came before the surveys of the upper portion of this Hadley Reservoir were completed, but it is already plain that its storage volume is only about half as great as supposed by Mr. Rafter. (See Sheet 11-B following p 156.)

22. A tour of inspection to learn the characteristics of the water-shed, and the character of present forest-cover on characteristic portions of the Hudson and Sacandaga water-shed was made, on which tour I accompanied a majority of the members of your Board and representatives of the power interests located between Palmers Falls and Mechanicville.

We proceeded by rail to North Creek, thence by wagon via North river to Indian Lake, and after an inspection of the dam, the sluice ways and margins of Indian Lake and the dead woods at Lewey Lake, proceeded southwesterly past Mason Lake, across to Lake Pleasant, thence around by Rudeston and Piseco Lake.

Inspection was made of dam site at head of falls on west branch of Sacandaga a mile or more below Piseco outlet, and of an excellent, large reservoir site on the south branch of Sacandaga, now mostly swamp land, extending nearly up to Arietta. Thence we proceed to Canada Lake, and thence across to Northville via Benson.

This tour was through the heart of the Sacandaga water-shed and showed a country substantially well forested, which, although completely lumbered over in years past for hemlock, balsam, spruce and pine, is to-day largely covered by dense, old growth hard wood and with much new evergreen growth. The hard woods cannot be floated down the rivers to the market, and so only the soft woods or evergreens have been cut off.

Everything seen gave evidence that this Sacandaga region is the most prolific source of the Hudson, subject to all the benefits that forest cover can give.

Westerly from North River village on the Hudson a few relatively small areas were noted where hillsides were bare and denuded, apparently as the result of forest fires long ago, in which the spongelike fertile humus had been destroyed.

23. A tour of inspection was made in September by Mr. Ropes and myself along the Schroon river, following the river road from the outlet of the lake down to Warrensburg, inspecting the Tumblehead Falls site and looking for other possible sites for power development.

It was at that time hoped to extend the surveys of the present season to include the possibilities of large storage on the Schroon. The sites for any large power development were not found particularly favorable, and the impression was gained that any future larger development of Schroon storage could best be used almost wholly for the benefit of the 400 feet of developed fall from Hadley to Troy rather than for local development.

With the great Sacandaga reservoir built there would probably be no need for the storage development on the Schroon for many years. Further surveys and study are necessary before even general conclusions about the reasonable extent of power development and of storage development in the Schroon valley can be reached.

GENESEE SURVEYS.

24. On the Genesee division, topography surveys have been made of the sites for a dam farther upstream than any heretofore proposed, in order to make certain that a suitable dam could be located entirely above the limits of the Letchworth Park.

A principal object in all my Genesee studies was to so plan a power development as to avoid marring the beautiful scenery of the Letchworth Park, and to determine if flood storage and a profitable amount of power development under public control could be attained and still leave fully as much water flowing over the falls in hours of daylight during the summer season as they now enjoy. The feasibility of a great power development without any serious impairment of the scenic beauty is demonstrated, but the questions of profit to the public from sale of power and of flood control need further study.

Surveys have been made for two alternative power house sites downstream from, and entirely outside of, the Letchworth Park. Topography has also been investigated along a proposed tunnel line, and the relocation of the railroad necessary to accommodate the proposed new dam site has been made.

Maps of the sites described in the preceding paragraph have been prepared on a scale of 100 feet to the inch, and traced on sheets of standard size.

25. Test borings have been made to determine the character of the substrata at various localities in the thinnest portion of the natural rim of the proposed great storage basin above Portage. Samples have been preserved and submitted to experts for classification. A contour map of this debatable ground has been prepared, also a cross section showing the results of the borings and the relation of the clay bank to the proposed water level.

We find that after penetrating a short distance below the present surface and before getting down to the highest water level proposed for the reservoir, the substrata are all of an extremely fine, compact and impervious material, commonly designated by those experienced in test borings as "clay."

The size of grains in the samples of sand overlying this clay seldom averages more than a few thousandths of an inch in diame-

ter, and in nearly all of the deeper strata the grains are so extremely fine as to insure a very high degree of imperviousness.

While additional surveys and many borings would in natural course be made prior to becoming actually committed to the construction of the proposed dam, the surveys and all borings thus far made concur in showing that not the slightest danger of leakage or rupture of this natural embankment is to be feared. At its thinnest point it forms a dam about half a mile in thickness measured at high water level, composed of extremely impervious material.

26. Outline designs for an arched masonry dam at this new Portage site, with a long spillway, have been made, and plans prepared sufficient for demonstrating feasibility and for purpose of a preliminary estimate of cost; and are submitted herewith.

27. Outline designs have been prepared for a power-house with turbines suitable for regularly supplying about sixty-five thousand horse power, working under a maximum head of about five hundred and fifty feet and are submitted herewith.

28. Novel designs for a tall surge tank to be located close to the end of the tunnel, for the purpose of relieving momentum waves, liable to occur in the exceptionally long water column of this tunnel under fluctuations of the power demand, have been worked out, and outline studies of the structures are presented.

29. Time and means have not sufficed for borings along the proposed tunnel line or at the alternative power sites, but the indications of the outcrop are that sound rock, very favorable for tunneling, will be found at the low level proposed; neither has time permitted a balance to be struck between the merits of the two alternative power sites, one having the shorter tunnel, the other the greater fall and power.

In general the best economy is found in concentrating all the fall at a single site and in getting the most out of the opportunity. The State should be as little wasteful as possible of its natural resources; therefore the first attention has been given to the lower site.

30. Following a chance suggestion, said to have been made by Lord Kelvin when he inspected the scenery at the Portage Falls, to which great importance has been attached by some of the Rochester journalists, careful study in the field has been made

concerning the feasibility of building a series of small dams and small reservoirs on the several tributaries of the Genesee above Mount Morris as a substitute for the one great dam and reservoir proposed above Portage.

After a study of the topographic maps and drainage areas a reconnoissance was made at each important tributary, to determine if conditions for dam and reservoir building were favorable, and what was the largest amount of storage that could be obtained. These studies were made under my supervision by an engineer of experience in water power development (Mr. George G. Shedd, see special reports, page 219) and prove beyond all serious doubt or question that the scheme of small reservoirs on tributaries, in place of a large reservoir on the main river, is utterly visionary and impracticable.

31. Outside inspection was made of substantially every building within the district proposed to be flooded by the Portage reservoir, with a view to estimating its probable fair market value.

Estimates of probable fair market value have also been made for all of the land to be overflowed. The figures thus obtained are regarded merely as a basis for a rough preliminary estimate of cost of acquiring the reservoir site. Although these figures are believed to average very closely to the real market value, it is recognized that costs of condemnation and the generous views which prevail in making settlements of this kind tend toward a total expense in the acquisition of real estate for reservoir purposes that is larger than the prior value. The sum total of the figures obtained as above has, therefore, been increased by 50 per cent. to cover legal expenses and other allowances.

32. As previously indicated, a study has been made of all of the long term rainfall records in the vicinity of the upper Genesee, with a view to learning if there were other periods when the rainfall and storage requirements were materially different from those existing during the period of gagings at Mt. Morris from 1903 to 1907.

33. A review of all published gagings of the Genesee river has been made and from these has been computed the probable yield at the Portage site, and the fluctuations in height of water in the

reservoir from month to month under various rates of constant draft has also been worked out, so that the margin of uncertainty is now small in the amount of power that could be produced at Portage and at Rochester from the proposed reservoir.

34. The records of the destructive Genesee floods have been reviewed in connection with a partial study of the restraining effect upon them of a reservoir used chiefly for water power, but to fully work out the Rochester and Genesee flood problem is a far larger task than could be brought within the scope of these studies of 1907.

FULL USE OF THE OPPORTUNITY.

At the outset it was determined to give the surveys and first studies such scope that the natural resources of each situation could be availed of to the greatest possible degree, and if obstacles were encountered as the studies progressed, then retrench in the design so far as economy might require.

A Sacandaga reservoir of greater area than any heretofore proposed was studied, in order that it might be possible to keep the main portion of the reservoir bed entirely covered by water even when drawn to the lowest point that the outlet gates would permit.

Since it appeared probable that by raising the flow line to an elevation some thirty feet higher than heretofore proposed, the artificial lake could be give the semblance of a natural lake with sandy beaches even when at its lowest level, and that it could thus be made a beautiful feature in the landscape at all times, and since with this greater depth it would never be necessary to uncover the present great swamp, risk of the reservoir becoming offensive would be avoided; the first study was directed toward a flow line at an elevation of 780 feet above sea, but after a fuller reconnoissance on the ground, the lower level of 770 feet was adopted, and so far as the present studies have shown, this high level of 770 feet is feasible, and the reservoir will give all needed storage if drawn only down to 740 in the most severe drought of the half century, being lowered only about ten feet in years of ordinary rainfall. Near some of the villages, on certain of the coves that

might otherwise have their beds uncovered when reservoir is drawn down, low earth dams can be cheaply built for preventing this, if found desirable.

Studies were made for the highest practicable reservoir level and for the lowest tail race level and for developing all upon a single fall because it appeared desirable in a project under State development to utilize to the utmost the water power that could be created, as well as to simplify the problem of future management and number of men required, by concentrating the entire fall for use in a single power-house and utilizing for power the full head of the lake. The higher the lake level the greater the power.

RESULTS IN BRIEF.

WATER POWER GAINED ON HUDSON RIVER.

Stating the results of general public interest thus far obtained, in briefest possible terms:

We find it very probable that on the Sacandaga there can be constructed a reservoir which will have at high water an area of about 40 square miles, or nearly the area of Lake George.

This will be so large that the surplus flood waters of years of heavy rainfall can be carried over to reinforce the flow of the river in years of small rainfall.

The extreme depth of water at the dam site will be about 60 feet, and will be about 30 feet when the lake is drawn as low as the sluices will permit.

In a year of ordinary rainfall the lake would be lowered not more than 8 or 10 feet, and in the year of smallest rainfall, such as is likely to come once in, say 20 years, it would never be drawn more than 30 feet. The area of the lake when thus drawn to the lowest level possible would be about 30 square miles.

This reservoir, although inside the line of the Forest Preserve lands, would be entirely outside the limits of the Adirondack Park, and I believe it feasible to so prepare its margins that the hills around it will become attractive sites for summer cottages, thus leaving the immediate region, after a few years, fully as populous and more prosperous than to-day, notwithstanding the number of houses that would have to be either submerged or removed.

This Sacandaga reservoir, as soon as built, will add most remarkably to the present water resources of the Hudson river by the release of its stored waters for use all the way from Corinth to Troy; and therefore the expense of construction of the proposed Sacandaga power-house, with its expensive tunnel, tailrace and electrical transmission lines, can be delayed as many years after the reservoir is built as thought desirable.

Until the proposed Sacandaga power-house is built, the sluice gates on this Sacandaga reservoir would ordinarily be nearly or

wholly closed during from four to six months of the year, and opened only during those six months of the year in which the flow of the Hudson is low.

I compute that under these circumstances the waters of this reservoir alone, with the opening of the gates varied from day to day as the varying flow of the main river may call for, would reinforce the flow of the main river to such an extent that the discharge at Mechanicville need never be less than 6,500 cubic feet per second where it now sometimes falls as low as 1,500.

The greatest regulated flow at Mechanicville contemplated in Mr. Rafter's studies of 1895, as a result of constructing the whole chain of proposed Adirondack reservoirs, was 4,500 cubic feet per second, but I find good reasons for believing, as just stated, that from this one reservoir of the size now proposed, a much better result can be obtained than heretofore hoped for from the storage control of all the ponds and lakes on the upper Hudson, including the Schroon.

This Sacandaga reservoir would more than double the present water power capacity of each mill site on the river during the two months of drought of the average year and would greatly increase the value of the undeveloped sites below Spier's Falls, which are said to have a fall of about 70 feet.

The average 24-hour 7-day discharge from this Sacandaga reservoir in the dryest month of a year of ordinary rainfall, as thus used for storage only, would be about 4,450 cubic feet per second, which would add nearly 125,000 available horse power in the aggregate, at the thirteen developed water-power sites from Corinth to Troy, inclusive, and about 20,000 horse power additional at the undeveloped sites between Spier's Falls and Glens Falls, over and above that which the river now furnishes in a similar dry month. Taking the six dryest months of the ordinary year, the aggregate in average amount of available power added at the several sites *during the dry half* of the year would be about 80,000 horse power of 24-hour 7-day power.

These are enormous quantities. The total of new power thus added at sites on the Hudson is larger than the aggregate water powers of Holyoke, Lowell and Lawrence.

TWO DIFFERENT METHODS OR STAGES OF USE.

In the early years, this Sacandaga reservoir can be used solely for storage for the benefit of the present water powers on the main river. In later years, its first and chief use would be for supplying a new power-house on the outlet from this great artificial lake.

The greatest good to the development of the State ultimately will come not from the use of this reservoir solely for storage in the interests of the mills on the main river, and care should be taken that no prescriptive or contract rights are gained, adverse to ultimately taking all the reservoir flow at substantially a uniform rate through the power-house proposed on the Sacandaga. Other reservoir sites can be then developed on other tributaries of the Hudson, for the sole benefit of the sites below Hadley.

Whenever it becomes expedient to construct the proposed power-house near Hadley, a tunnel about two miles in length will have to be built under the mountain, and the down-stream mile of the Sacandaga (which is found by our borings to contain no ledge), will need to be excavated or dredged for a deep tailrace.

The Hadley power-house can then use all of this water under a head and fall of nearly 200 feet, and with turbines of ordinary efficiency this would yield constantly about 25,000 to 30,000 horse power on the turbine shaft if drawn at a uniform rate for 24 hours per day and 7 days in the week throughout the year, but as more profitably used, and concentrating a large part of the use into the ordinary working hours of the week, with a 40 per cent. load factor, loads aggregating upward of 60,000 horse power, as measured at the consumers' end, allowing 85 per cent. efficiency for electrical conversion and transmission, could be supplied throughout a dry year, and transmitted in part for municipal purposes to Albany, Troy, Cohoes, Saratoga, or any of the communities within a radius of upward of 50 miles.

My own views are that it should be the policy of the State to develop new uses or to supply solely public needs at cost, rather than to enter into competition with established power plants by offering their manufacturing customers lower rates. Temporarily with a portion of this power sold to them at wholesale the building of the plant proposed would greatly benefit those established power plants now suffering a shortage.

Near to the power-house, a new industrial community could be founded and supplied with a part of this great power, for the total of 25,000, or 30,000 horse power of 24-hour power, or 60,000 horse power in ordinary working hours, just mentioned as available at this one power-house, is greater than the aggregate water power of Lowell and Holyoke combined.

The greatest utility to the State would be obtained under a system designed to encourage local development of new industrial communities, rather than by leasing this power to private corporations for the purpose of replacing, because of lower cost, power now obtained by the burning of coal.

For twenty years or more of the immediate future, pending the gradual encouragement and development of industries of the kind in which the maximum population per thousand horse power is supported, it would be wise for the State to seek markets for the surplus portion of this power where it would simply cheapen the cost of manufacturing or street railway service or electric lighting by replacing power now derived from burning coal.

Temporarily perhaps leases might also be made for electrolytic or other use consuming large amounts of power rather than to let the water run to waste, but the fixed and plainly expressed policy should be to set a time limit to such leases and try to ultimately have this power put to such use as will employ in new enterprises as near to this power-house as practicable large numbers of highly skilled operatives.

BENEFITS OF SACANDAGA POWER PROJECT TO EXISTING WATER POWERS ON THE HUDSON.

Athough the uniform discharge through the Sacandaga power-house will reinforce the existing power sites on the Hudson between Corinth and Troy and enlarge their capacity to a less extent than the intermittent discharge during the first period mentioned, when the Sacandaga sluices are closed tight for several months in the year and its storage discharged wholly in months of drought, the uniform discharge from the proposed power-house nevertheless will be, as already stated, of great benefit in adding to the power at all of the sites from Corinth to Troy inclusive.

For example, in September, 1907, the Sacandaga river in its

natural state was delivering only about 130 cubic feet per second into the Hudson, whereas with the proposed reservoir built and its water used exclusively through the proposed power-house about one mile west of Hadley, the corresponding discharge from the Sacandaga would be 1,700 cubic feet per second. This additional 1,570 cubic feet per second of 24-hour flow, for example, on the 75-ft. drop at Spier's Falls, would add 10,000 horse power of 24-hour 7-day power.

An estimate made in much detail from the records of Hudson flow during the past 20 years, shows that the aggregate increase in power, by the uniform draft through the Sacandaga power-house all the way from Corinth to Troy, would average nearly 22,000 net horse power increase of 24-hour 7-day power on the turbine shaft for the six dry months in the year.

The facilities for building an enormously thick and high earth dam here by the hydraulic sluicing method practiced in the West apparently give means for abundant safety within limits of reasonable cost.

Should it be deemed after further investigation that so high a dam as the one now being studied which would impound 56 ft. in depth of water, is not feasible, a lower dam can be adopted and a good power and storage proposition still be obtained. And while I would not yet undertake to pronounce finally on feasibility or cost, I do heartily recommend further investigation.

I have been unable to find anywhere within the State of New York (unless it be at Niagara), another site which promises to be so well adapted to development under State ownership and control.

Private interests have for four or five years past been obtaining property and rights with a view toward the development of this Sacandaga power under much less comprehensive plans than those which I have worked out and under conditions which will bring far less new power and far less benefit to the State.

ADVANTAGES GIVEN BY STATE OWNERSHIP AND CONTROL.

The State, obtaining its money by bond issues at less than two-thirds the annual charge that a private company has to meet when the ordinary discount and bonus are reckoned in, can afford to

expend a part of this difference in a better preparation of the reservoir site and in more ample and permanent structures.

Moreover, the State can doubtless find means to properly assess upon each of the owners of the thirteen or fifteen power sites along the Hudson a fair rental value for the increase in flow by which the power at each plant would be practically doubled, while it is probably impossible to form a combination of all the mill owners in which each would co-operate properly and contribute his fair share toward the full success of this large work.

Again, under private ownership and control the building and emptying of the more shallow reservoir proposed, in which vast swamp areas would be uncovered at the end of a summer drought, might be a distinct disadvantage to the surrounding communities of Batchellerville, Northville, Northampton, etc.; while on the other hand the larger and deeper reservoir proposed to be built by the State, with its steeper banks and well prepared bed, with projecting stumps removed, and with its sandy beaches, and with its sluiceways so arranged that by no possibility could the water be drawn so low as to uncover the swamp bottom, would furnish an added attraction to these beautiful villages.

I have no doubt that this great artificial lake could be made such an attractive feature in the landscape that summer cottagers would seek its shores as they do the shores of Canada Lake near Gloversville, or the shores of Sebago Lake in Maine, or Lake Winnepiscogee in New Hampshire, both of which have dams at their outlets and serve as storage reservoirs for water power. Sebago is about 25 per cent. larger than the proposed Sacandaga lake, has about half its drainage area, and its extreme rise and fall under storage control is about 10 feet.

In Indian Lake reservoir, built by a corporation understood to comprise in part the same interests that now seek control of the Sacandaga, we have an example of methods of clearing a reservoir bed that were regarded by the power interests as satisfactory and were a vast improvement over earlier methods; yet the protruding stumps of this reservoir bed are a menace to the safety of pleasure boating, and in general appearance when partially empty, the bed and margins of Indian Lake are a wretched failure in comparison with what might be.

Early action by the State is required lest this most favorable of all present opportunities for the development of a great power by the State for public use near populous communities be lost.

THE IMMEDIATE PROJECT OF PRIVATE DEVELOPMENT.

The immediate purpose of the Sacandaga development proposed by the Hudson River Electric Power Company, which has been in part set forth in a recent application to the State Public Service Commission for authority to make a bond issue for purposes of construction, is to build a timber dam about 20 feet high about four miles farther up the stream than the best dam site. This location is adopted in order to avoid flooding small pieces of State land comprised in the Forest Preserve. The dam is to be kept low to avoid flooding the railroad which runs from Gloversville to Northville.

It is proposed for an indefinite period to use the stored water solely for increasing the flow of the Hudson at the present mill and power sites all the way along from Palmers Falls to Mechanicville, in time of drought.

For this purpose the sluice gates at the proposed dam would probably remain closed during the storage months, from December to May or June inclusive, and would be opened only for a total of about 100 days, mostly in July, August and September, but sometimes also opened in case of a winter drought, thus treating this storage somewhat according to the methods now followed at Indian Lake.

No prospect of founding a new industrial community is presented in this private development.

Under the Company's plans it is proposed to develop at some future time a power-house on the outlet from the proposed Sacandaga reservoir, by means of a secondary dam, located some three miles westerly from Hadley and under conditions whereby only about half as great a fall would be obtained as under the plans which I have submitted for State development. This electrical power so developed would presumably nearly all be transmitted to Albany and other cities for lease to public service corporations, or for taking the place of power otherwise generated from coal.

In other words, the principal effect of this second and final stage of this private development would be to use this water power for replacing power already developed, whereas if developed under State control it is proposed that preference should be given, by favoring rates, to the local development of new industries and to the founding of one or more new industrial communities, thus adding far more to the taxable resources of the State. The State project being on a larger scale, the ultimate population set at work by the Sacandaga water could be of more benefit to the State.

SAFETY OF TEMPORARY SACANDAGA DAM PROPOSED BY HUDSON RIVER POWER OWNERS.

It is worthy of consideration in connection with a proposal to build a temporary, timber overfall-dam, that the river bed at Conklingville and below and probably all along for some miles, runs over a buried gorge filled more than a hundred feet deep with sand, and that this condition in view of the volume stored, demands very great precautions in type and foundation of the main dam. I see no reason yet to doubt the possibility of building a safe dam, but it cannot properly be a cheap type of dam. The United States Census Report of 1880 calls attention to the repeated carrying out of dams on the Sacandaga between Conklingville and Hadley, because of the sand foundation, and of all the various dams and water power developments that have in times past existed along this stream, only one remains, and that is broken out at one end.

GENESEE STORAGE AND POWER INCREASE.

The second study, undertaken at the request of the county supervisors of Monroe county, relating to the building of a great storage reservoir on the Genesee above Portage, partly for the purpose of flood control, partly for power, where it is found that a dam, power-house and all appurtenant works can be built entirely outside the limits of the park presented to the State by Mr. Letchworth, and without substantial injury to its scenic beauty.

It appears that after reserving for scenic purposes at the Genesee Falls a volume greater than the present midsummer flow, the

water stored in this great reservoir in the flood season, could generate power for electrical transmission sufficient to deliver about 32,000 24-hour 7-day horse power throughout the year, or about 80,000 horse power if concentrated during ordinary working hours with a 40 per cent, load factor, at Rochester, Mt. Morris and other localities in that part of the State, or for establishing a new industrial center in the neighborhood of the power-house, beside adding at the several water plants now in operation within the city of Rochester, an average of about 8,700 24-hour 7-day horse power, or about 22,000 horse power if used in ordinary working hours under a 40 per cent. load factor during the six dry months of the average year. In the dryest month it would in all add to them an average of about 13,500 of 24-hour 7-day horse power.

If the dam were built and the power-house with its long tunnel and other expensive structures delayed for some years, and the reservoir used meanwhile solely for reinforcing the low water flow at Rochester for purposes of power development, sewage dilution and flood control, it would add in the dryest month of the average year nearly 32,000 horse power of 24-hour power at the existing developed power sites, and the average addition during the six dry months of the average year would be nearly 20,000 horse power of 24-hour power, which if used mainly in working hours, or under 40 per cent. load factor, would add about 50,000 horse power.

PROMISING SITES NOT YET STUDIED.

Elsewhere than upon the Sacandaga and the Genesee, there are many inviting opportunities for investigations. The sites for water storage for power upon the Raquette river, the Black river, the Oswego river and certain other Adirondack streams give promise of developments that would add greatly to the resources of the State, and the Sacandaga is only one of several great reservoir sites on the Hudson which are each well worthy of development for increasing the power at the present dams, all the way from Palmer's Falls to Troy. At the heads of the "Finger Lakes" and on the tributaries of the Delaware, there are said to be opportunities well worth investigating.

POSSIBLE BETTER USE OF THE NIAGARA RESOURCES.

Niagara, too, offers a most important field for further investigation. While for the time being a halt has been called in the diversion of water from Niagara, the Canadian power movement appears to be gaining such strength and to be obtaining such a hold on public sentiment, that it is not improbable that further developments will come, and that each further diversion for power upon the Canadian side will prompt a corresponding diversion upon the American side.

It is proper that the people of New York should have available for reference a broad impartial study of the Niagara situation, with designs for obtaining the utmost value from each gallon of water diverted and for combining benefits to navigation with benefits from power transmission, rather than that projects of further development should be left wholly to questions of first cost, or to convenience or caprice of private parties, or that control should follow the chance ownership of lands along the line of development.

At certain of the recent Niagara power plants, nearly half of the total fall available between the head of the falls and Lewiston is wasted, and a given quantity of water, therefore, performs only half the work that it might perform. Under commercial conditions, it has been necessary to obtain the quickest possible return for the smallest immediate outlay.

A reconnoissance indicates that it is entirely feasible to make all further power developments at Niagara part of a more comprehensive plan in which deep draft steamship navigation on American territory should be provided for through a great power canal that would permit the water for power to be utilized under substantially the entire fall of 316 feet.

This can be worked out in entire harmony with and be helpful toward the development of the proposed deep waterway from the great lakes to the ocean by way of the Hudson and New York city.

DETAILS OF WORK OF 1907.

In the following pages the work and the results outlined in the foregoing pages in a non-technical way, will be described more fully from the technical standpoint, giving some of the reasons that governed the selection of the specific lines of study, but stating all as briefly as clearness and proper record for the use of those who follow in the work will allow.

SCOPE OF INVESTIGATION.

In brief, chapter 569 of the Laws of 1907 directs that the State Water Supply Commission "at once proceed to collect information relating to the water powers of the State," and to "devise plans for the progressive development of the water powers of the State under State ownership, control and maintenance, for the public use and benefit and for the increase of the public revenue."

Two lines of inquiry are ordered, the first relating to the feasibility and cost of specific projects; the second relating to the broad general subject of State water power development, including a financial plan and the draft of a bill for carrying the final recommendations into effect, "in order that the Legislature and the people may have before them at once the most complete and comprehensive statement of the possibilities of the water power of the State."

The Commission is required to designate which work of development should be first undertaken and which thereafter.

The meaning of the term "the water powers of the State" is ambiguous. In a broad sense, it may mean all undeveloped power sites within the borders of the State, or in a more restricted sense may mean those undeveloped water powers, where either the water rights, or the site, or both, are now owned by the State. From a study of the antecedents of the bill, there can be no doubt that the undeveloped storage reservoir sites, lying within the State lands of the Adirondack Forest Reserve, and available for increasing the water power of the Hudson river were also included under this term.

This act No. 569, 1907, also provides that study may be given to plans for the development of "such other water powers" as may be brought to the attention of the Commission by the mayor of a city, or other chief municipal officer.

That a good degree of thoroughness and precision was contemplated by the act is shown by the specification in section 4 of the act, that reservoir storage capacities in cubic feet be ascertained, that the rainfall recorded on the watershed be reported, and that maximum average and minimum flow of the stream for each month of the year at any proposed dam, be ascertained in cubic feet per second. The act moreover calls for statements of the amount of power that could be developed, the probability of selling it, the probable gross and net revenues, the cost of structures, lands and riparian rights, etc., and in section 8, it is specified that "All final surveys, plans maps, calculations and estimates made pursuant to the provisions of this act shall be made with the same accuracy that would be requisite if the work and project so surveyed had been ordered to be done." So far as this work has yet been carried, I have sought to comply with this specification.

For carrying out the investigations thus specified, the sum of $35,000 was appropriated, and a date was suggested for presentation of the final report only eighteen months subsequent to the date when the bill became a law.

For such broad scope and great thoroughness as are thus specified in the act, the appropriation was insufficient and the time too short. The entire appropriation and the entire time allowed are smaller than I have sometimes found it necessary to expend on the surveys and studies for a single project of water power development before those financially interested were ready to decide upon actual construction.

Stream gagings, test pits, borings and accurate surveys are all very expensive and without them the quantity of water power and the cost of reservoir building cannot be accurately foretold.

Therefore, my first work was to review the field with much care and to select a small portion of the work evidently contemplated by the legislative act, such that while complying in thoroughness of investigation with the plain requirement of the law as far as the appropriation would allow, and keeping strictly

within its limts of time and funds, the facts learned would best illustrate the general subject and present to the Legislature and to the people of the State in the progress report specified for February 1, 1908, the greatest possible amount of information upon the possibilities of water power development under State control.

It has seemed best to carry on this work of investigation vigorously while the funds lasted and thus to secure for presentation a year earlier than otherwise, the important facts regarding two or three of the subjects of greatest interest.

ANTECEDENTS OF THE FULLER BILL.

In deciding upon the precise scope of the work to be first undertaken, it appeared necessary to consider a little the history of events leading to the legislative act under which we were working.

In the message of Governor Hughes, presented to the Legislalature on January 2, 1907, under the topic Forest Preserves and Water Powers, after speaking of the further acquiring of forest tracts, he said:

> "In this connection it is well to consider the great value of the Water Powers thus placed under State control. They should be preserved and held for the benefit of all the people and should not be surrendered to private interests. It would be difficult to exaggerate the advantages which may ultimately accrue from these great resources of power if the common right is duly safeguarded."

He said further, in relation to the work of the State Water Supply Commission:

> "It remains to be considered whether it is not advisable to provide a more comprehensive plan embracing in a clearly defined way the matter of water storage and the use of water courses for purposes of power. The entire question of the relation of the State to its waters demands more careful attention than it has hitherto received, in order that there may be an adequate scheme of just regulations for the public benefit."

The response of the Legislature to this suggestion by the Governor, and to the protests urged by the Association for the Preservation of the Adirondacks against indiscriminate reservoir construction, is found in the Fuller Bill.

THE HUDSON'S IRREGULAR FLOW, AND THE ADIRONDACK STORAGE POSSIBILITIES.

It has long been recognized that the magnificent water power sites along the upper Hudson river at Hadley, Palmer's Falls, Glens Falls, Fort Edward, Sandy Hill and Mechanicville, all fall far short of their possible utility by reason of the extremely small flow of the river during the droughts of summer, and its small flow when the brooks that feed the river are icebound.

This undesirable irregularity in flow of the Hudson and certain other streams of Northern New York, has retarded their employment in the finer and more expensive mechanical processes such as textile manufacture and the other uses found along the Merrimac and other New England streams where storage has more generally been provided, and which finer manufacturing processes attract and support much larger industrial populations per horse power than the processes of pulp grinding and paper making, for which the Hudson water power continues to be chiefly used. Perhaps in the long run even the paper industry cannot hold its own in this locality against the lessening supply of pulp wood within convenient reach, if continuing handicapped by irregular power, or by the cost of making the supply of power regular by means of steam.

Storage reservoirs on the Hudson's head waters, supplying more uniform flow of water at the present industrial centers will surely add to their present development, and will in time tend to bring in new uses, supporting larger populations.

Until about twenty-five years ago lumbering had been the chief industry that called for water development on the Hudson above Troy; and sawmills require cheap power and cannot afford large expenditures per horse power in power development. Pulp mills, which followed, are but a refinement of lumbering, and also call for cheap power; and so until recent years the plea for

storage reservoirs has been based largely on the ground of the improvement in navigation that it was believed would result from reservoir building.

REVIEW OF PREVIOUS INVESTIGATIONS.

While organizing our survey parties and planning their work, a review was made of all previously published reports that it was thought were likely to present information useful in the present investigation. A brief abstract of the data found in these reports that are of special interest in the present study, is given below, both for data itself and for the purpose of making the reasons for our present lines of enquiry more clear. It appears to be a popular belief that most of the possible Adirondack reservoir sites have been already studied with a fair degree of thoroughness.

THE MCELROY REPORT OF 1867.

The report made to the N. Y. Canal Board relating to a survey of the Hudson river to Fort Edward, etc., and transmitted to the Senate, February 15, 1867, contains many interesting facts regarding possible improvements for the benefit of the navigation of the upper Hudson and some brief allusions to the water power that could be gained incidentally thereto, but it is plain that the attention at that time was focussed mainly upon navigation, and we find little data on storage or power development in this report which has not been replaced by later and more complete information. Mr. McElroy called attention to the great damage along the Hudson from floods and recommended surveys for storage reservoirs for flood relief and briefly called attention to their value for water power.

ADIRONDACK STORAGE REPORT OF 1874.

In the annual report of the Canal Commissioners of the State of New York for the fiscal year ending September 30, 1874 (p. 83), Farrand N. Benedict, C. E., formerly professor of mathematics and engineering in the University of Vermont, acting under authority of legislative act of April, 1874, presented a very interesting report upon the regulation of the flow of the Hudson by means of great storage reservoirs proposed to be constructed

in the Adirondacks, and presented brief descriptions and rough estimates of cost of developing these very remarkable sites.

He describes the survey as made "with reference to increasing the supply of water for the Champlain canal and improving the navigation of the Hudson river."

Prof. Benedict describes his "survey" as "more properly a reconnoissance," and a study of his report shows plainly that it was hurried and was very far from exhaustive or complete. The extent of the work by the parties under his supervsion was mainly confined to visiting each of the considerable Adirondack lakes, so far as time allowed; selecting by surface inspection the most eligible sites for dams, determining by hasty methods the area of those lakes which it was proposed to utilize for storage, to measuring the height and width of the cross-section of the valley at the proposed dam sites, and to running a few lines of levels connecting with levels previously run for railroad or other purposes, in order to determine the elevation and flow line of some of the proposed reservoirs. He compiled data from sundry previous surveys and says that his work was greatly facilitated by previous familiarity with the region, without which he could not have covered nearly so much ground with the time and means at his disposal.

His proposed dams were to be of log cribs packed with stone without cement, of about the same general type as commonly built by lumbermen, and were of a design far cheaper and far less durable than would today be demanded, particularly in work to be built by the State. His approximation from scant data to the annual depth of rainfall and runoff available for filling these reservoirs was shown by the more complete later records to have been much too large.

Prof. Benedict recommended cutting the timber on the reservoir sites before flooding, but in those days apparently little thought was given to such thorough clearing of the reservoir sites by removing dead timber and stumps as the public interest now demands, and no recommendation was made for preserving sanitary and cheerful conditions by reserving a depth below the drain gate level sufficient to keep any swampy portions of the bed of the basin always covered by water.

It may be regarded as on the whole fortunate for the public that no authority was given for construction on these crude plans and according to the standards of those early days, and fortunate that but a small amount of large reservoir construction was undertaken in the years immediately following this report and before public sentiment had been aroused against the old time methods of reservoir building in the forest.

Considering the brief time and scant funds at his disposal Prof. Benedict collected a large amount of very interesting information. He says in his report: "To make these determinations satisfactorily demanded an amount of time and means far beyond that authorized by the act of the Legislature;" and he also says of his work of demonstrating these great opportunities for water storage, that "he had confidence that enough of the subject could be developed to show its vital importance and its true relation to the public interests."

A table summarizing the results of Prof. Benedict's investigation on the Hudson headwaters above Indian river is presented on the following page. In reviewing this, it should be borne in mind that he found part of his estimated storage for increasing the flow of the Hudson river by diverting into the Hudson drainage water naturally tributary to the Raquette river, in a way that would not be feasible in view of the present large water power developments upon the Raquette.

From all of these 28 ponds above Indian river, he estimated only about 18.4 billion cubic feet of storage, including about 12 billion cubic feet proposed to be diverted from the Raquette into the Hudson. *All of those proposed by Prof. Benedict on the Hudson above Indian River give only about 6 billion cubic feet.*

Note the small depth of most of the reservoirs and the small cost estimated for the several dams in the following table.

It should also be noted that the Benedict reservoirs reported in the following, all lie upstream from Indian river, and that the reservoirs reported upon by Mr. Rafter in 1895–6, all lie on tributaries entering below Indian river.

Prof. Benedict also submitted some notes on reservoir sites below Indian river, particularly within the Schroon drainage, which are not reproduced here because data on these appears more fully given in the Rafter report of 1895.

STORAGE RESERVOIRS POSSIBLE ON HEADWATERS OF HUDSON AND RAQUETTE RIVERS ABOVE INDIAN RIVER,

According to Prof. Benedict's Survey of 1874.

(From U. S. Census of 1880, Water Powers, Part 1, Page 347.)

NAME OF PROPOSED RESERVOIR.	Elevation above tide.	Drainage area.	Natural surface.	Flowage.	Total surface of reservoir.	Depth of reservoir.	Capacity.	Estimated supply per second for 100 days	Estimated cost of dam.
	Feet.	*Sq. M.*	*Acres.*	*Acres.*	*Acres.*	*Feet.*	*Mil. cub. ft.*	*Cub. ft.*	
Blue Mountain Lake	1,771	39.2	2,500	160	2,660	10	1,158	134	$7,300
Raquette Lake	1,745	94.1	5,300	1,500	6,800	10	2,779	321	6,600
Forked Lake	1,726	39.8	1,620	510	2,130	7	609	70	5,600
Beach's Lake	.....	8.6	640	160	800	8	250	29	2,100
Long Lake	1,614	155.4	3,000	4,575	7,575	20	5,912	684	14,000
Round Pond	1,618	.....	.....	.....	640	10	278	32	.....
Catlin Lake	1,583	31.1	1,040	500	1,540	18	815	94	22,000
Rich Lake	1,549	67.1	600	400	1,000	20	609	70	28,600
Harris Lake	1,540	.....	720	600	1,320	15	627	73	16,700
Lake Henderson	.....	.....	.....	.....	.....	12	209	24	5,800
Newcomb Lake	1,699	30.6	640	200	840	15	483	56	13,800
Lower Works Reservoir	.....	57.2	.....	.....	2,000	15	1,306	151	24,700
Chain Lakes	.....	14.9	1,680	300	1,980	10	862	100	6,000
Goodenow Pond	.....	0.25	320	.....	.....	6	83	10	7,900
Goodenow River Reservoir	.....	7.8	.....	480	.....	12	250	29	8,800
South Pond	1,769	.....	.....	.....	.....	12	188	22	5,000
Clear Pond	1,691	.....	.....	.....	.....	10	217	25	7,000
Slim Pond	.....	.....	.....	.....	.....	10	196	23	5,000
Ackerman Pond	.....	.....	.....	.....	.....	10	87	10	5,900
Perch Pond	.....	.....	.....	.....	.....	12	167	19	3,300
Trout Pond	.....	.....	.....	.....	.....	12	125	14	4,400
Lake Harkness	.....	.....	.....	.....	.....	12	104	12	3,100
Shedd Lake	.....	.....	.....	.....	.....	10	209	24	4,100
First Sergeant Pond	.....	.....	.....	.....	.....	10	87	10	3,900
Third Sergeant Pond	.....	.....	.....	.....	.....	10	217	25	3,200
Plumley Pond	.....	.....	.....	.....	.....	11	258	30	4,100
Moose Pond	.....	.....	.....	.....	.....	11	182	21	5,500
Cary Pond	.....	.....	.....	.....	.....	10	139	16	4,772
	.....	.....	.....	.....	.....	.....	18,419	2,128	229,172

Total cost of Long Lake improvement estimated by Mr. Benedict at $196,600.

Aggregate cost of improvements, including $14,800 for dam to control Little Tupper Lake (designed in Mr. Benedict's plan to be used as a reserve for both the Hudson and Raquette Rivers), and a total of $196,600 for Long Lake, placed at $426,572.

From these reservoirs on extreme headwaters alone and exclusive of Cedar, Boreas, Indian, Schroon and Sacandaga rivers, it was thus estimated that an increase of upward of 2,000 cubic feet per second in summer flow of Hudson could be secured at an expense of between $400,000 and $500,000 as estimated by Prof. Benedict and for dams of the lumberman's type.

REMARKS ON PRECEDING TABLE.

(From Census Report.)

Blue Mountain Lake.— Reservoir includes the three lakes, Utowana, Eagle, and Blue Mountain; lies naturally in Raquette Basin, but via Long lake can be diverted to the upper Hudson. Estimated that winter and spring drainage would fill reservoir 1.87 time.

Raquette Lake.—Waters proposed to be diverted from Raquette river to Hudson. Estimated that winter and spring drainage will fill reservoir 1.87 time.

Forked Lake.—Waters to be diverted from Raquette to Hudson. Estimated that winter and spring drainage will fill reservoir 3.6 times.

Beach's Lake.— Tributary to Forked lake. Estimated that winter and spring drainage will fill reservoir 1.88 time.

Long Lake.— This lake naturally drains through the Raquette river, but, by cutting a canal across a low divide, can be connected with Round pond, and thus be made tributary to the Hudson. Estimated cost of bulkhead, canal, and outlet through slough at foot of lake, $154,000. Estimated that winter and spring drainage will fill reservoir 1.056 time.

Round Pond.— From Round pond to Catlin lake there is a fall of 35 feet in about 4,000 feet.

Catlin Lake.— Estimated that winter and spring drainage will fill reservoir 2.1 times.

Rich Lake.— Northern shore heavily wooded; southern cleared. Outlet narrow and rocky, with bold shores. Proposed dam would flow about 200 acres of improved land.

Harris Lake.— Estimated that winter and spring drainage will fill Rich lake and Harris lake reservoirs about 3 times. Harris lake is the lowest member of a chain composed of these lakes mentioned above.

Lake Henderson and Newcomb Lake.— Estimated that winter and spring drainage will fill reservoir 3.5 times. This lake is surrounded by high mountains on every side except the east.

Lower Works Reservoir.— Estimated that winter and spring drainage will fill reservoir 2.4 times. Advantages for dam not so good as at some of the other sites. Includes Lake Sanford.

Chain Lakes.— Estimated that winter and spring drainage will fill reservoir 5 per cent. of filling the reservoir.

Goodenow Pond.— Reservoir to be formed by dam on Goodenow river. Estimated that winter and spring drainage will fill reservoir 4.13 times.

Goodenow River Reservoir.— Reservoir to be formed by dam on Goodenow river. Estimated that winter and spring drainaage will fill reservoir 1.72 time.

South Pond, Clear Pond and Slim Pond.— Drain to Long lake.

Ackerman Pond.— Tributary to Catlin chain of lakes.

Perch Pond, Trout Pond, Lake Harkness.— Drain through central or mountain branch of Hudson.

Shedd Lake, First Sergeant Pond and Third Sergeant Pond.— Drain to Raquette lake.

Plumley Pond, Moses Pond, Cary Pond.— Drain to Forked lake.

UNITED STATES CENSUS REPORT ON NEW YORK WATER POWERS.

An excellent report upon the water powers of New York and those of the Hudson river in particular, prepared by Dwight Porter, now professor of hydraulic engineering at the Massachusetts Institute of Technology, is found in a special volume of the United States Census of 1880 relating to the water power of the United States, page 346, *et seq.*

This report, though nominally bearing date of 1880, was not completed until some years later. It presents a very full description of the several power sites as developed in 1882, with estimates of the total power available at each under various conditions, and also an abstract of Prof. Benedict's report on the in-

crease of river flow to be gained from the construction of storage reservoirs in the Adirondacks.

It is of present interest to note the attitude regarding the construction of storage reservoirs at that time, described as follows in page 348 of the Census Report:

> "Although the building of reservoirs in the upper waters would benefit all the hydraulic powers on the course of the river below, it does not seem probable that their construction will be attempted by private capital. The mill owners considered that the State would receive as much advantage from reservoirs by reason of the improvements of low water navigation below Troy as any private interest would receive and are not disposed to invest their own capital in such enterprises, so long as there is a possibility that they may be undertaken as public works."

One specially interesting statement in Prof. Porter's Census report regarding the low water flow of the Hudson (p. 346) given on the authority of Mr. Warren Curtis, than whom no man is better informed on Hudson river matters in general, is that at Palmer's Falls the flow for one or two months in the year sometimes falls as low as 200 to 250 cubic feet per second. This would be a little less than 0.10 cubic feet per second per square mile, or about the same as we found for the watershed above Indian river near the end of the August drought in 1907, or about the same that we found for the entire Sacandaga at that time. This is, however, far smaller than anything found in the more recent gagings recorded for Fort Edward and Mechanicville.

Since the recorded flow at Mechanicville in low water, as published from year to year in the reports of the U. S. Geological Survey and of the New York State Engineer, is much larger than I should expect from a drainage area of this character and area, the following quotation is presented for its caution and as a reason for measuring the flow at various points on the main river carefully by independent means whenever there is another severe drought and at the same time making note of the stored water being released from Indian lake and Schroon lake or from lumbermen's reservoirs.

Water Power, U. S. Census, 1888, vol. 16, Part I, p. 346:

> "At Palmer's Falls, there is a favorable opportunity for determining the low water discharge, and observations have been made at various times by Mr. Warren Curtis, Superintendent of the Hudson River Pulp and Paper Co. Mr. Curtis states that the average low flow at that place for, say, the four months of least volume is not far from 400 or 500 cubic feet per second, and that for one or two months it is not more than 200 to 250 cubic feet per second. October 28, 1882, a measurement was made which indicated a discharge of about 390 cubic feet per second."

Although I incline to the opinion that the Mechanicville record in time of drought gives too large a quantity, I regard the above estimate as surely too small, but it serves in urging the need of additional precise gagings.

At the beginning of the present investigation in August, 1907, it was intended to take these Census tables of 1882 and the Rafter tables of 1895 as a starting point and bring the statistics of water power for New York in general and the Hudson, Genesee and Raquette rivers in particular up to date, presenting for each site detailed estimates of the power that could be gained by storage development. It was proposed also to resurvey portions of the profile of the Hudson where power is not yet developed from the fall. The only progress so far made upon this has been to collect some data showing the increasing development of power from year to year and relating to the turbines now in use upon the Hudson and Genesee rivers and giving the falls under which these turbines work, and the total flow that can be taken through them, all as set forth in tables on the following pages.

It is interesting to note that by reason of the large number of turbines devoted to supplying power for grinding wood pulp, a greater profitable use of irregular power, or power which can be relied on during only a few months of the year, is possible here at many of these Hudson river plants than would be economical in most other lines of manufacture.

The use of power throughout the 24 hours of the day at a uniform rate, prevails to an uncommonly large extent at these Hudson river power developments. This is a result of the power being so largely devoted to paper manufacture.

For purpose of comparison and checking and for showing recent growth, the estimates of total horse power developed at each site in 1899 has been copied in parallel column from Mr. Rafter's table in New York Hydrology, published by the New York State Education Department in 1905.

From this comparison it appears that during the past nine years an addition of 50,000 horse power of turbine capacity has been made available for use in the months when water is plenty, thus more than doubling the turbine capacity of nine years ago, and that about 6,000 horse power additional is to be installed soon.

Mr. Rafter found in 1895, according to p. 150 of State Engineer's report for that year, a total of only 43,841 net horse power in use on the Hudson at Troy and above, including that at Hadley and that on the Schroon and Sacandaga. The amount comparable with the totals of the following table was 40,070 horse power.

The total amount found by Prof. Porter in 1882 at all developments on the Hudson and its tributaries above Troy was 12,896.

This remarkable increase of 25 years from about 12,000 horse power in 1882 to 40,000 horse power in 1899 and 98,000 in 1907, with 6,000 horse power more of additions in immediate prospect, indicates plainly that use would be found within comparatively few years for all the additions that could be had from the storage of the Sacandaga floods.

DATA AS REPORTED ON HUDSON RIVER POWER PLANTS BELOW MOUTH OF SACANDAGA RIVER.

LOCATION.		ORDINARY WORKING HEAD.										
Place and drainage area.	Mill and use.	Gross.	Net.	Number of turbines (number of runners).	Approx. net horse-power actually developed in 1899 (Hyd. p. 639†).	Ordinary discharge (cubic feet per second).	Ordinary power when water is plenty (net horse-power).	Catalog discharge, full gate (cubic feet per second).	Catalog horse-power, full gate.	Total developed horse-power per foot of gross fall.	Total developed horse-power per foot of gross fall per 1,000 square miles of drainage area.	Remarks.
Hadley		18	.....	.....	1,350	.....	.....	.....	.....	.....	.....	
Palmer's Falls, approximate, 2725 square miles.	International Paper Company, No. 3, pulp grinding, etc.	.....	84	2	.....	360	2,700	360	2,700	.....	.....	
		84	49	13	.....	2,170	9,650	2,170	9,650	.....	.....	
		.....	34	18	.....	2,900	9,270	3,100	10,100	.....	.....	
					14,500	*	21,620	*	22,450	268	99	
Spier Falls, approximate, 2760 square miles	Hudson River Water Power Co., electric power.	75	75	(12)	.....	4,400	26,500	4,900	29,500	394	143	
Undeveloped fall		68	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Canal feeder dam		11	.....	.....	1,450	.....	.....	.....	.....	.....	.....	
Glens Falls, approximate, 2785 square miles.	International Paper Company, No. 1, Finch Pruyn Company.	.....	38	9	.....	1,440	4,950	1,500	5,157	.....	.....	1,765 H. P. additional to be installed not included here.
		39	21	3	.....	570	1,088	570	1,088	.....	.....	
		.....	17	4	.....	245	374	245	374	.....	.....	
	Pulp grinding, etc.	.....	39	16	.....	2,560	9,038	2,640	9,333	.....	.....	
		.....	.....	.....	7,931	*	15,450	*	15,952	409	147	
Sandy Hill and Baker's Falls, approximate, 2795 square miles.	Union Bag & Paper Co., Mills Nos. 1 and 2, paper machinery power, etc.	.....	12.5	14	.....	3,810	4,333	3,810	4,333	.....	.....	Turbines of 902 H. P. not used at present and not included.
		.....	20	7	.....	1,175	2,140	1,175	2,140	.....	.....	
		70	22	4	.....	110	244	110	244	.....	.....	
		.....	27	3	.....	340	836	430	1,060	.....	.....	
		.....	28	3	.....	340	858	340	858	.....	.....	
		.....	32	3	.....	385	1,167	385	1,167	.....	.....	
		.....	55	6	.....	730	3,100	840	3,800	.....	.....	
		.....	.....	.....	4,793	*	12,678	*	13,602	194	70	
Ft. Edward, 2,800 square miles		18	18	62	6,393	4,305	6,950	4,305	6,950	386	138	

Crocker's reef.....	.....	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	Barge canal dam.
Fort Miller, approximate, 2950 square miles.	Ft. Miller Pulp & Paper Co.....	9	9	14	1,485	1,455	1,176	1,600	1,289	143	49	
Saratoga dam.....	.....	18	18–9	.....	3,130	.....	.....	.....	.....	.....	.....	
Stillwater, approximate, 3,680 square miles.	Hudson Valley Traction.....	7	7	3	514	910	580	910	580	83	22	
Mechanicville, 4,500 square miles.	W. Va. Pulp & Paper Co.....	17.5	17.5	.....	3,355	3,610	6,090	4,130	6,586	376	84	4,032, H. P. to be installed and is not included.
	Hudson River Power Co.....	18	18	.....	3,000	4,230	6,800	4,720	7,600	422	94	
Troy.....	.....	7	.....	.....	1,345	.....	.....	.....	.....	.....	.....	
Total excluding Hadley and Crocker's Reef.....	.....	441.5	.....	.....	47,896	.....	97,854	.....	.....	.....	.....	

* Note that at some mills the same water is used twice by subdividing the fall. Therefore the sum of wheel capacities would be greater than the maximum flow used.
† This column from Hydrology 1905, page 639. All other columns give data for Dec. 1907.

UPPER HUDSON STORAGE REPORT OF 1895.

Under chapter 599 of the Laws of 1895, a survey of the upper Hudson was provided for with a view to determining what lakes and streams could be improved by storage, the object being to provide for:

1. The enlargement of the Champlain canal.
2. For restoring water equivalent to that diverted for canal purposes.
3. For improving the navigation of the Hudson river.

Another object which although not mentioned with the three above was perhaps quite as important in the minds of some of those interested in this work, was that of adding greatly to the water power of the several mill sites on the Hudson, all the way from Hadley to Mechanicville, and this important matter received due treatment in the report.

These surveys of 1895 were made under the general supervision of the State Engineer and the Superintendent of Public Works, and the report is included in the volume of the report of the State Engineer and Surveyor for the year 1895, pages 87–195.

The work was in the immediate charge of Mr. George W. Rafter, Civil Engineer, an engineer of much experience in the study of hydrology and an enthusiast in matters relating to the regulation of stream flow by storage reservoirs for the increase of the water power resources of the State.

It is fortunate that the work was put in charge of one who so fully appreciated the lack of precise data existing at that time that he laid a foundation for our more complete studies of today by urging immediate co-operation between the New York State Engineer's office and the United States Geological Survey for an accurate topographic survey of the Schroon drainage. The preparation of maps of that region was followed within a few years by similar maps of the entire Adirondack region.

In his report Mr. Rafter presented extensive tables and hydrographs of the flow of the Hudson river, based upon the daily records of height on dam and turbine run, which had been maintained for seven years previous by the Duncan Co. at its dam and paper mill at Mechanicville and he had other gagings begun on the Hudson and on the Schroon.

The funds provided at that time were utterly insufficient to permit much field work of a precise or detailed character in the study of dam sites or flowage lines, but it appears that a broad general reconnoissance was made, visiting nearly every noteworthy lake or pond upon the Hudson head waters. Other than the topographic surveys arranged for with the U. S. Geological Survey by the State paying half the cost, and which appear to have absorbed half the entire appropriation, the new surveys in detail for this storage study appear to have comprised only the following:

1. A line of levels was run from which a water power profile of the Hudson was prepared, covering the sixty-five miles from Glens Falls to North River village.

2. Surveys and studies for a large dam at Tumblehead Falls on the Schroon river and for another dam and reservoir at Indian Lake were made with some detail, though based on no sufficient test pits or borings. The outlines of Piseco Lake were surveyed at present level and also for a higher flow line.

3. Dam sites were partially explored and estimates of cost prepared, on Boreas Pond, Cheney Pond, Piseco Lake, at Starbuckville, at Hadley and on fifteen sites for smaller reservoirs tributary to the Schroon.

The chief conclusions of Mr. Rafter were:

1. That by constructing a reservoir system wholly to the south of the Benedict system given in table on page 63, having a total storage volume of 41,593,000,000 cubic feet, estimated to cost $2,606,559, the mean monthly flow at Glen Falls with the river thus regulated, need not fall below 3,000 to 3,600 cubic feet per second, whereas it then at times fell as low as 900 cubic feet per second under natural conditions.

This storage volume to be provided was equivalent to a depth of 12.5 inches of run-off on the entire watershed directly controlled, of which about 1.5 inches was for use of the log drivers.

2. He fixed upon 4,500 cubic feet per second flow as the proper minimum at which the river should be maintained, *for reasons connected with the navigation,* and concluded that the regulated flow with the proposed total storage of 41,593 million cubic feet, would maintain at all times not less than 4,500 cubic feet per

second of 24-hour flow at Mechanicville, or 1.0 cubic foot per second per square mile.

3. Mr. Rafter concluded from some comparison of gage heights that this increase in flow, due to storage, would increase the low water depth in the Hudson river at Albany about 1.5 feet.

4. Mr. Rafter estimated roughly that by thus regulating the flow through storage reservoirs, the maximum possible continuous power of the Hudson river, if each fall all the way from Troy to North River village was developed, would be increased by 114,020 horse power to 174,020 horse power twenty-four hours per day, whereas the same falls under present conditions would yield in time of low water only 60,000 horse power. He thus reckoned that the power available in the dryest months of the ordinary year would be increased nearly threefold.

5. Attention was called to the opportunity for a large succession of power developments of moderate size along the upper Hudson from Thurman to North River village, the river having a total fall of 450 feet in twenty-five miles. This would require the relocation of the Adirondack railroad higher on the side of the valley.

6. A new census of the Hudson river power developments was presented, showing a total turbine capacity of 43,481 net horse power, a most remarkable increase from the 12,894 found by the census made by Prof. Porter in 1882.

7. It was suggested that during the season while storage was accumulating, a constant flow equivalent to 0.45 cubic feet per square mile of drainage was to be left flowing in the streams, but the detailed estimates showing just how this was to be done and meanwhile fill these very large reservoirs are not presented in the report.

On a close analytic study, this report of 1895 is found to contain very far from complete information on the water storage problem, and nothing more than a reconnoissance could properly be expected from so small an appropriation.

It is made plain in the report, upon close study, that the above estimate of cost of $2,606,559 for 41,593 million cubic feet of storage was very crude, and that the data for it were few.

Mr. Rafter also called attention to the possible opportunity for a great reservoir above Conklingville, by the erection of a dam twenty feet high, thinking it probable 4,000,000,000 cubic feet of storage could thereby be obtained, but said as there was "no definite data at hand as to the effect of twenty-five feet rise on the valley, it is considered best on the whole to leave this reservoir for the present out of the account."

The chief permanent results of this survey of 1895 are:

1. The earlier securing of accurate topographic maps of the Adirondack region.

2. The publication of carefully prepared tables of the daily flow of the river.

3. The securing of the data which led to the construction of the Indian Lake dam in 1898.

INCOMPLETENESS OF DATA SECURED IN 1895–6.

Since these figures upon storage, taken from the reports of 1895 and 1896 have been often quoted without making plain the scant data on which they rest, it is worth while to briefly show how they were derived.

For ten drainage areas, mostly small and near the head waters, it was assumed in the absence of definite surveys but after some reconnoissance in the field, that dams at the lake outlets could be built sufficient to store the total run-off of the storage months, December to May inclusive, in the minimum year, which was estimated as equivalent to a depth of 13.5 inches over the entire watershed.

Taking Mr. Rafter's data, the lakes and the drainage areas proposed to be utilized for storage are as follows:

Pleasant and Sacandaga lakes	45	square	miles
Arietta Flow	10	"	"
Thirteenth Pond	14	"	"
Chain Lakes on Rock river	58	"	"
Catlin	25	"	"
Lakes Rich, Morris, Newcomb and Goodenow.	83	"	"
Lake Henderson	18	"	"
Lake Sanford and Tahawus	67	"	"

Cedar river.	58	square miles
Sundry small areas on Sacandaga with definite data lacking, estimated at.	50	" "
Total	458	" "

If the yearly flow from all these could be controlled by dams so as to store the depth of run-off estimated at 13.5 inches over this entire area of 458 square miles, the volume would be equivalent to 458 x 5,280 x 5,280 x $\frac{13.5}{12}$ =14,364 million cubic feet.

In the absence of definite information, Mr. Rafter thought that the average cost of all of this storage in the ten areas of lakes given above, would not exceed $76.48 per million cubic feet stored. This $76.48 was found by estimating in some detail the total cost for a series of sixteen reservoirs *on the Schroon system* and by dividing the total estimate of $1,172,500 thus found, by their total estimated storage of 15,330,000 cubic feet.

It was by this very crude method that the cost for the ten reservoirs on upper Hudson and upper Sacandaga proposed built to hold 14,364,000,000 cubic feet, was estimated at $1,098,559.

On Boreas and Cheney Ponds, it was estimated that 1,111 million cubic feet of storage would cost	$118,000
On Indian Lake it was estimated, apparently from surveys in detail, that 4,468 million cubic feet of storage would cost.	120,000
On Piseco Lake, it was estimated that 1,725 million cubic feet of storage, which apparently would raise the lake level about 12.7 feet, would cost. .	70,000
At Tumblehead Falls, it was estimated from surveys that a high masonry dam could be built which would raise the level of Schroon Lake about thirty-one feet above its present level of 807 feet above the sea or when the reservoir was filled to maximum flood depth with two feet flowing over the crest of the dam, the water would be raised to contour 840.	

At Tumblehead Falls the water level would be raised fifty-nine feet, and the proposed dam would impound the run-off from 502 square miles.	
The vast reservoir formed by this dam would flood also Brant Lake and Paradox Lake.	
It was estimated that the total volume thus stored including the thirty-one feet of extra depth on Schroon Lake at Tumblehead Falls, would be nearly 16 billion cubic feet, and the expenses attendant on flooding this vast territory was then estimated at	$840,000
It was also proposed to construct a dam on the main Hudson river just above the present highway bridge between Hadley and Luzerne, where it was assumed, apparently from very meagre surveys, that there could be impounded 4,000 million cubic feet at a cost of.....	360,000

The totals of the above estimates were:

Storage 41,593 million cubic feet.	
Total cost	$2,606,559

So far as can be judged from the report, it appears that data used for estimating the volumes of the proposed great Schroon reservoir were chiefly the contours at twenty foot intervals, as determined by the ordinary topographic methods of the U. S. geological survey, and not very precise because of the scale being so small and the points actually located being so few.

In the case of the proposed Hadley reservoir, the area to be flooded is so long and narrow that topography mapped on so small a scale as one mile to the inch, could not be expected to give a close approximation, but the topographic maps of the U. S. geological survey as well as our own partial surveys of 1907 indicate only about one-half as great a volume as assumed by Mr. Rafter.

His estimates for dams at Hadley, Tumblehead Falls, Indian Lake, Piseco Lake and for Boreas and Cheney Ponds, so far as

may be judged from the description in the printed report, were made with some degree of care, from measurements of the cross section of the valley at the points selected for dams.

The type of dam is described (in table 15, page 174 of State Engineer's report of 1895) as "in general, earth dams with masonry cores and provided with waste ways over natural rock at the side," but in the case of the larger dam for Tumblehead Falls and Indian Lake, massive masonry structures were proposed and the cost of the dams themselves appears to have been estimated in some little detail. The actual cost of construction at Indian Lake came very close to this preliminary estimate.

The type proposed at that time for the great dam at Tumblehead Falls was a loose rock fill, to be made water tight by an asphalt-concrete facing. This is a type of construction which would hardly be accepted to-day.

HUDSON STORAGE REPORT OF 1896.

In his report of the previous year, Mr. Rafter plainly stated that his data were incomplete and reserved the right upon obtaining further data, to change his figures upon storage volumes and cost and a continuation of his studies of 1895 is reported under date of February 1, 1897, upon pages 803–858 of the State Engineer's report for the year 1896.

This reports additional surveys at the site of the proposed dam at Tumblehead Falls, at the Hadley Dam site, and for dam sites at Tahawus, Lake Henderson, Boreas River and at Newcomb. The survey had been completed for the Indian Lake dam site to the point where it was said, that if desirable an appropriation could be made for its construction.

The test pits at Tumblehead Falls failed to reach ledge at thirty-five feet below the surface on the south side; and owing to the lack of sufficient appropriation, borings for completely determining the character of the sub-strata could not be made. The report says that "hard material" was in general found from ten to twenty-four feet below the bed of the river. Presumably this means compact sand, hard-pan or boulders — not solid ledge.

A topographic map of the Tumblehead site on a scale of 100 feet to an inch was prepared but not published.

At the Hadley site, the probable cost was found greater than estimated the year before, because it was now found that more of the houses in the village would be included within the flow line, and that the river at the dam site was much deeper than had been supposed.

The topographical work was not extended over the Hadley reservoir, and therefore no accurate figures on its storage volume were presented.

A further study of rainfall and runoff of the upper Hudson region was reported, and a compilation of many monthly rainfall records and temperature records was presented. Considerable space was given to the recurrence of years of exceptional small stream flow.

Except for the small amount of new survey and test pit work mentioned above, the report of this year 1896 upon Hudson river storage was mainly made up of a compilation and discussion of such data as are to be found in the library, rather than by a presentation of the data that could be had only through additional field work and at larger cost.

INVESTIGATIONS BY WATER STORAGE COMMISSION OF 1902.

Under Chapter 406, Laws of 1902, a Commission was appointed to investigate causes of floods and overflows of rivers and water courses and make recommendations for preventing the same.

The members served without salary, and an appropriation of only $5,000 was made to cover salary of secretary traveling expenses, printing and the service of an engineer and assistants to be detailed from the office of the State Engineer.

The Commission resolved itself into four committees for greater facility of work, and the State was correspondingly subdivided into four districts for investigation. Circulars were sent out calling for statistics of injurious floods, and the Commission recognizing the insufficiency of the appropriation, confined its work for that year mainly to "the preliminary work of collecting general information concerning the distribution and extent of floods throughout the State to the ascertainment of the general character and extent of the injury sustained thereby

and to the general type and character of the remedial measures available."

"It was expected that the preliminary investigation of the first year would show just what problems existed and what further special investigations and surveys were needed before actually undertaking the work of flood prevention or stream measurement in the various portions of the State."

"The conclusion was reached that State supervision and control is the only safe method of intelligently initiating, constructing and maintaining an adequate study of river improvement for this State."

"The central idea should be that the entire cost of the execution and maintenance of each of the various works comprising such a study, should be borne by the beneficiaries in proportion to the benefits they derive from it."

Attention was particularly called in the report of this Water Storage Commission to the possibilities of large additional water power development upon the Genesee, Hudson and the Black rivers by means of the storage of flood waters.

The Commissioners reporting for the eastern division, Mr. Elnathan Sweet of Albany and Mr. George R. Finch of Glens Falls, in their statements about the Hudson river region above Troy, p. 148, present the following interesting notes:

On the Hoosic about one mile above its mouth, a reservoir of five billion cubic feet could be located but would be costly above $200 per million cubic feet.

On the Battenkill, about five billion cubic feet of storage could be secured by dams of Battenkill and Shusan, both located above the principal water powers. This storage would cost probably not more than $100 per million cubic feet.

On Fish Creek, the outlet of Saratoga Lake, about three billion cubic feet of storage could be secured, costing probably not more than $100 per million cubic feet, but the Commissioners state clearly that additional surveys are needed to determine the facts with more precision.

They further state (p. 149) that the surveys of the Hudson River Electric Company indicates that a storage reservoir holding, say, 8,000 million cubic feet can be made at Conklingville

by raising the surface of the mill pond there about 24 feet, at a cost not to exceed $75 per million cubic feet, that is, $600,000.

On the west branch of the Sacandaga, the Water Storage Commission caused a reservoir site to be surveyed half a mile above the Little Falls, where a dam 62 feet high would store 7.5 billion cubic feet at a cost not exceeding $40 per million cubic feet.

On the east branch of the Sacandaga, a reconnoissance indicates 3.5 billion cubic feet can be stored at the Griffin and Oregon and at the outlet of Lake Pleasant, all at moderate cost.

These three reservoirs aggregating 19 billion cubic feet were deemed sufficient for the regulation of the Sacandaga. (See p. 149 Rept. Water Storage Com. 1903).

On the Schroon River, Messrs. Sweet and Finch reported recommending a modification from Mr. Rafter's plan of a single large dam at Tumblehead Falls, which would flood and connect Schroon, Paradox and Brant lakes, because of the said plan providing more storage than consistent with utilizing the full water power of the Schroon, and because it would have to be executed all at one time and would necessitate too radical a change at Schroon Lake.

They suggested instead of the dam at the Tumblehead site, a dam about a mile and a half above Starbuckville, which would raise Schroon Lake to elevation 817 above sea level, and which would supply three billion cubic feet of storage.

They also recommended four other dams, viz., at the foot of Brant Lake, to provide 1.8 billion cubic feet of storage; Paradox Lake, 2.2 billion cubic feet; at Blue Ridge 1.5 billion cubic feet; at Loon Lake and Hammond Lake, 1 billion cubic feet, a total of 6.5 billion cubic feet.

The whole Schroon River system of reservoirs thus planned would aggregate 9.5 billion cubic feet, which Messrs. Sweet and Finch believe could be provided at a cost of less than $70 per million cubic feet.

For the upper Hudson River, they suggested:

1. Fully developing the storage of Indian River by a dam at the head of Indian River Falls about four miles below the recent new Indian Lake dam, providing four billion cubic feet of storage.

2. By dams on tributaries above Indian River to provide 3.5 billion cubic feet; and on Boreas River at the outlet of Cheney Pond, providing 1.5 billion cubic feet, the whole aggregating with the present Indian Lake dam 14 billion cubic feet on that division of the watershed.

The cost of the Indian River storage was estimated at only $5 per million cubic feet, and that of the other reservoirs on this division at $75 per million cubic feet.

They further recommended securing four billion cubic feet of storage at the reservoir recommended previously on the Hudson River at Hadley (our later surveys indicated this reservoir would contain only about half this quantity) and four billion cubic feet additional by a reservoir to be created by raising the State canal feeder dam located two miles above Glens Falls about 45 feet or to elevation 333 above sea level and stated that the costs of these two reservoirs may approximate $100 per million cubic feet.

	Billion cubic feet.
The total for upper Hudson was	14.0
The total for Schroon was	9.5
The total for Hoosic was	5.
The total for Batten Kill was	5.
The total for Fish Creek was	3.
The total for Sacandaga, Conklinville was	8.
The total for Sacandaga, West branch was	7.5
Total	52.0

In conclusion, they stated that this study of regulating reservoirs for the upper Hudson "would not only secure the desired regulation of the lower Hudson, but would provide a like regulation to all its upper tributaries, thus serving in the highest degree the potential energy in the stored water for the development on the tributaries as well as on the main stream and would benefit navigation by providing ample feed water for the proposed enlargement of the Champlain Canal and by raising the minimum low water stage of the Hudson River in the shallow portion below Troy, *more than one foot.*"

It will be noted this is more conservative than Mr. Rafter's estimate of 1.5 ft. increased depth from 41.6 billion cubic feet of storage, but it is not quite clear if they considered all of the 52 billion cubic feet of storage necessary to gain this one foot of depth.

In reviewing the above conclusions, it should be remembered that Messrs. Sweet and Finch had the benefit of no additional surveys and no precise data, but that both were presumably very familiar from long personal experience with the general characteristics of the territory in question.

RESTRICTIONS ON RESERVOIR BUILDING.

Notwithstanding all the foregoing evidence of remarkably favorable reservoir sites, by the use of which the great shrinkage of the river's flow in summer could be prevented and notwithstanding the requirements of navigation and the great need for more power, various causes have deferred the building of additional reservoirs in the Adirondacks.

In the earlier days, lack of combination of the various mill owners along the stream for united action, and lack of securing a pro rata contribution to the cost of the reservoirs, doubtless had much to do with preventing action by them.

Combinations of this kind even when plainly most advantageous are often difficult to bring about. One mill has less pressing need than another of adding to its supply of power. Some mill owners may not have the ready funds. The owner of a mill may reason that those mill owners whose need is greatest will go ahead with the reservoir building and that by waiting, without effort or expense on his part, he can enjoy the use of the stored water as it flows past his mill, and as suggested in the census report already quoted on page 65 there has been all along a hope that the State would undertake this work with little or no expense to the mill owner, "for the benefit to navigation."

The fact that one using power for grinding pulp, the purpose for which the Hudson power is chiefly used, can not afford so large an expense for power as in textile manufacture, and can more readily arrange to manufacture a surplus in the months of plenty and stop in the months of drought, has also been a factor.

FOREST PRESERVE RESTRICTIONS.

The establishment of a State Forest Preserve in 1890 has had a very important restraining influence on the construction of these storage reservoirs.

The State laws outline two large districts, designated respectively as the Adirondack Park and the Adirondack Forest Preserve, comprising all lands owned or acquired by the State in certain counties and towns.

The outlines of the two districts and the location of the several parcels now owned by the State are shown on certain large scale maps issued by the N. Y. Forest, Fish and Game Commission.

The inner circuit bounds the "Park Lands" and the outer circuit the "Forest Preserve." The Park is a part of the Forest Preserve.

The Adirondack Park as laid out and already about four-fifths acquired, is confined to a contiguous and nearly solid tract, roughly rectangular in shape, averaging about 80 miles across from north to south and about 70 miles from east to west. It consists largely of land from which the valuable coniferous timber had been removed by lumbermen prior to its purchase or recovery by the State, but as a whole, it is still densely covered by the primeval hardwood growth, comprising many magnificent trees, and contains many acres where a new stand of small spruce, balsam, hemlock and pine is rapidly growing.

The Forest Preserve *outside the park* consists of many large and small detached tracts, widely separated and scattered within a zone varying from 20 to 50 miles in width outside the *park, but comprises only a very small percentage of all the lands in this zone.*

In the State Constitution, it is now provided, act VII, section 7 — "The lands of the State now owned or hereafter acquired, constituting the forest preserve as now fixed by law, shall be forever kept as wild forest lands. They shall not be leased, sold or exchanged or be taken by any corporation, public or private, nor shall the timber thereon be sold, removed or destroyed." This provision has come to have a wider scope than those who

framed it probably foresaw, since under certain laws, scattered tracts of land in various parts of the State on which taxes have ceased to be paid revert to the State and become parts of the State forest preserve and subject to the limitations above set forth.

Many small detached tracts of abandoned farm lands, of deforested timber lands and of valueless swamp lands have thus come into the possession of the State and are thus held as part of the forest preserve under the restrictions quoted above, and some of these tracts happen to stand within areas desirable for reservoir purposes.

An instance of this kind is found within the area proposed to be acquired by the city of New York as the site of its great Ashokan reservoir now under construction for purposes of domestic supply. A notable instance is found within the proposed limits of the Sacandaga reservoir, about four miles above Conklingville.

An amendment to the State Constitution may be necessary to remedy these conditions.

In some instances, the land proposed to be flowed is practically worthless for the real purpose of a forest preserve and can be employed for water storage with far greater advantage to the State than in any other use.

For example, in the neighborhood of the great Vly swamp between Cranberry creek and North Broadalbin, or near the long level swamp on the West Branch of the Sacandaga, upstream from the entrance of Piseco outlet, the conditions affecting health and pleasure would surely be improved by converting both of these tracts into storage reservoirs, under proper requirements for cutting the trees and removing the stumps, and for burning all dead timber and other refuse wood, and then flooding this swamp by a dam whose drain gates were set so high that the swamp would become forever covered by water.

EFFECT OF LUMBERING UPON STREAM FLOW.

A clear distinction must be made between deforesting for agriculture and the cutting out of the timber trees, in their effect on stream flow.

As a matter of fact, the vast lumbering operations of the past 75 years have probably had little, if any, measurable effect upon

the flow of the Sacandaga river, for those areas where the forest fires have raged so fiercely as to destroy the leaf mold, denude the soil and prevent new growth, although large to the eye, are so far as I have yet been able to learn, but a small percentage of this whole upper Hudson drainage area, and I saw no such denuded areas on the Sacandaga drainage.

Perhaps in some parts of the Adirondacks, the tracts of barren burned land are larger than on the Upper Hudson drainage area.

The dense Northern forest, as seen on our tour through the Indian Lake and Sacandaga drainage already described, comprises magnificent old-growth, hardwood trees left after the lumbering and filled in between with underbrush, which soon grows up again after a small fire, all of which efficiently shade the ground and check the wind movement over the surface and thus lessen evaporation and also furnish sponge-like leaf mold to soak up and retain the rain, so that all of this forest region probably yields at the present day just about as much run-off and just about as even a flow as ever before, the only material difference probably being that the winter's snow was better shaded by the old-growth of evergreens from early melting by the sun.

The new growth of small evergreens doubtless soon restores this shade, and except for the constant menace of fires severe enough to burn the humus and the collection of "spruce duff," there is every reason to expect that the yield of the upper Hudson will forever continue much the same as now, especially so since the recent wise establishment by the State of a great Forest Preserve.

The real storage which regulates the summer yield is not in the forest or in the accumulation of leaf mold but is in the porous sands beneath. The forest cover and the leaf mold retard the run-off and give it more time to soak into the porous sand.

The complete deforesting for purpose of agriculture undoubtedly makes a great decrease in the summer run-off, but the drainage area of the Upper Hudson is mainly too steep, too cold and too sterile for agriculture and will always remain mostly woodland.

Forest fires are the great and pressing danger to maintenance of the volume of stream flow and to its partial regulation by forest influences and the consequent lessening of the extremes of flow between flood and drought.

Means for lessening the present danger of forest fires may well be considered by those who would conserve the sources of the water power of all this region.

Near North Creek can be seen examples of the injury, irreparable largely for a hundred years, that may sometimes follow a forest fire. The unmerchantable standing trees and the underbrush, that furnished shade to retard the melting of the snow are gone, and the sponge-like, fertile covering of leaf-mould and humus that it has taken many years to accumulate is lost. With this protection gone, the scanty covering of earth that it has taken unknown years of frost and disintegration to accumulate over the rocks of the hillsides, soon becomes more or less washed away by the rain. Scant shelter or nourishment is left for new growth to come in, which by giving shade and lessening the wind movement would lessen the evaporation, and by accumulating leaf mold and duff would present a sponge-like surface to retard the flow, and so for many years the rainfall upon these burned barren tracts will run rapidly to the rivers, the snows will melt rapidly and the summer flow of the springs will dry up early.

I was much impressed by these facts as I traveled in September last across the lower half of the Adirondack Preserve from North creek past Indian lake to Lake Pleasant and Piseco lake and along the west branches of the Sacandaga.

A forest to serve its best purpose should not be simply let alone. Portions of the admirable forestry laws recently established by the United States Government under the wise lead of Mr. Gifford Pinchot, may well serve as a basis for remodeling the foresty laws of New York, and above all the construction of main lines of roads for quick access in fire control and the presence of forest wardens and the presence of scattered small colonies of settlers who may get their living as guides or wardens or keepers of summer vacation camps and thus have a direct interest in preservation of attractive forest conditions, should be encouraged by wise provisions of the State laws.

All this will result in ultimate benefit to water powers and to the many other products of the forest. Likewise, all that can be done to extend the plantations of thickly set pine — cheaply set out about five feet apart by the tens of thousands or hundreds of

thousands, as has been done in recent years by a few far-seeing land owners — will be of benefit to the stream flow and to the resources of the State.

POPULAR OPPOSITION TO STORAGE RESERVOIRS.

In recent years, the apprehension of the general public lest the attractiveness and healthfulness of the State forest reserves as a pleasure ground would be seriously impaired by the flooding of vast tracts for reservoirs to be emptied in midsummer, has on various occasions aroused a strong sentiment against any extensive reservoir building.

Methods of reservoir building that have too freely prevailed in New York, in Maine and other states, whereby large forest areas have simply been flooded, thereby killing the trees and the underbrush, and leaving them to slowly rot amid scenes of hopeless desolation, have given abundant cause for these popular fears and protests.

Also there are many object lessons within the limits of the Forest Preserve, of reservoirs nominally "cleared" before flowing, where the timber has been so cut as to leave tall stumps exposed and decaying as the stored water is drawn off and there exist other examples of reservoirs with stumps partly submerged that make pleasure boating dangerous, all offensive to lovers of nature and to those who would find pleasure in a vacation spent along the water-courses.

In recent years, the needs of the mills, and particularly the needs of the new electric power transmission plants, for more water power and for a less variable flow, have become more urgent, and more strongly than in former years the water power owners have joined forces in advocating reservoir construction and in expressions of willingness to join in the cost, but meanwhile the public has become awakened to the dangers and has become more jealous of its rights.

PROPER RESERVOIR BUILDING SHOULD BE ENCOURAGED.

Whether a storage reservoir site is made dismal or beautiful is in most instances a simple question of expense and supervision.

It appears certain that by a proper cutting of stumps and bushes, by the careful limitation of high water and low water levels according to the lay of the land, and by the action of the waves in undercutting the sod and digging out the roots on moderately steep slopes, thus in time forming sandy beaches, the margins of a partly emptied artificial storage reservoir having steep, sandy or rocky banks, as found almost everywhere in the Adirondack mountain region, can be made sanitary and attractive, particularly under State supervision, and it is certain that large storage reservoirs can be built at various places upon the headwaters of the Hudson, Raquette and other rivers, which will add to the attractiveness of the region to health seekers and pleasure seekers, and that such reservoirs may be made to contribute greatly to the industrial prosperity of the State and should be built.

RULES BY WHICH STORAGE RESERVOIRS MAY BE MADE ATTRACTIVE.

After personal inspection of several of the sites now in question and some study of the local conditions, and from my observations upon many reservoirs for domestic water supply and upon the shores of many natural lakes, I am led to believe that with the following requirements rigidly enforced, the public interests would be fully safeguarded, and that *the larger reservoirs, although used for power, would on the whole, in comparison with present swamps and bushy or marshy margins, surely add to the pleasures of the forest.*

1. Up to a contour at least 3 feet above high water, and out to not less than 25 feet from the water's edge, all trees and underbrush should be cut close to the surface of the ground and all projecting stumps should be removed, excepting only the covered roots, and all of this wood and refuse should be rigorously burned and none left to sink or drift as described at Indian lake. For average conditions of heavily forested land, this would probably cost $25 per acre. The cutting and burning of the trees on a thousand acres of Indian lake margins is said to have cost about $15 per acre, but that clearing was not so complete as it should have been.

2. The dams should be given such surplus height as to provide sufficient storage without ever completely emptying the reservoir or exposing large flat level areas that would be badly drained as the water receded, and no drain gate should be permitted to be built at a level so low as to permit this complete emptying or drawing below a predetermined level.

3. In order to fix this lowest limit of draft, no storage reservoir should be authorized to be constructed until a large scale contour map of its bed is presented, upon which the character and elevation of all parts of the basin are shown, so that the effect of draining to the proposed limit may be studied and ample drainage ditches may be prescribed where found necessary, in order to prevent pools or swampy areas being left on the benches or terraces. A scale of 100 feet to an inch with a 2-foot contour interval is suggested for ordinary situations.

4. Wave action by its erosion and overturning of the soil at high water and as the waters slowly recede, works powerfully upon the sandy or gravelly slopes of the wider portions that are exposed to the wind, and experience shows that this action soon results in creating many sandy or gravelly beaches similar to those found on natural ponds.

Along sheltered coves and on very flat slopes, or on unfavorable soil, this beach-making action may not occur, but a few grassy coves may add variety to the scene and add to the cover for birds and the minor animal life of the woods.

Many examples of storage reservoirs with fluctuating water levels can be found which are attractive and beautiful. Piseco lake is subject to several feet of rise and fall, but nevertheless has a beautiful shore. Spot pond, a reservoir of varying height in the center of the North Metropolitan park of the Boston district, forms the central feature in a beautiful landscape.

PROPOSED REMOVAL OF CONSTITUTIONAL RESTRICTION.

In 1907, prominent water power interests along the Hudson and Raquette rivers joined with others in promoting the passage of an amendment to act VII, section 7, of the Constitution of the State of New York, by inserting a clause excepting from the

restrictions described above, such forest lands as the Legislature should decide were required for the storage of water for public purposes.

In a paper by John G. Agar, read March 14, 1907, at a convention called in opposition to this constitutional amendment at the Albany Chamber of Commerce and published by the Association for the Preservation of the Adirondacks, Tribune building, New York city, the popular side of the case against the construction of storage reservoirs in the forest, under private control, is stated with great force.

Incidental to his main argument, Mr. Agar states, page 9: "For the water power there should be a well defined plan of water storage and reservoir system to be constructed, maintained and operated, with the power derived therefrom to be sold or leased by the State and the proceeds thereof to be used for public purposes," and he strongly urged that the present safeguard against the acquisition by private parties, of vested rights in the water flow and water power, be not sacrificed.

CONCERNING WATER POWER DEVELOPMENT IN GENERAL.

No State in the Union is so bounteously endowed by nature with great opportunities for water power development as is the State of New York, especially if the developments possible upon the international boundary rivers, the Niagara and the St. Lawrence be counted in; yet the general course of water power development for industrial uses was, relatively to the opportunity, much slower in New York than in the New England States until the marvelous electrical developments of the past few years and until the full value of the exceptionally high heads at Niagara and Rochester was realized.

During the past five years, water power development everywhere has been more active than ever before.

There are no new sources open to discovery; the watersheds and rivers are now all on the map, and their falls and rapids are all open to any man's observation. Under the stimulus of long distance electrical transmission what was economically impossible a few years ago, is now practicable and profitable, and with the

impending increase in cost of coal, this utilization of all available water powers will continually become more complete.

Today few, if any, available power sites of noteworthy size or importance can be found on which the promoter has not already begun some work of development, or secured an option. Of course, the tendency is to seek a quick financial return, to cut out the best portion and waste the remainder, to seek a quick market by replacing steam power in established industries rather than to establish new industries, and if the State is ever to make a broad study of this question with a view to such development as shall to the utmost conserve these great sources of power in nature for the fullest benefit and convenience of man, or if it is to take action in reserving for public use those power sites yet remaining within its direct control, now is the time.

A DISADVANTAGE OF LONG DISTANCE ELECTRICAL TRANSMISSION OF POWER COMPARED WITH LOCAL USE.

It is well for those who make laws designed to secure the best development of industrial conditions within the State to recognize that the development of a great water power for transmission by electricity to some distant city where it will merely serve to lessen the amount of steam coal burned in old established industries, adds less to the prosperity and population of the State than local use in new industries, and that long distance transmission builds few new factories and homes such as followed when the Merrimack river was dammed at Lawrence or the Mohawk power developed at Cohoes.

Large water power developments prior to the invention of electrical transmission were commonly unprofitable. The early stockholders of the water power companies that developed Cohoes, Holyoke, Lewiston and Lawrence, either lost all or waited long, because their large expenditure for lands, dams and canals came nearly all at once and rolled up interest charges while the power still largely ran to waste, waiting for the slow process of an industrial development sufficient to absorb any large proportion.

With electrical transmission all this was changed, the power became immediately available as a cheaper source than steam for

large industries already well established, or could be immediately sold in large blocks to large users like street railways or public lighting companies, and the great source of immediate profit in nearly all recent water power enterprises has been thus found in taking the power to some large city and stopping the steam engines.

THE INDIAN LAKE RESERVOIR.

This appears to have resulted from the surveys of 1895–6. It is the largest and most recent storage reservoir in the Adirondacks and one in which the State has acquired an important part. It adds materially to the water power of the Hudson in time of drought and therefore it merits at least a brief mention in connection with the present studies. The following description is condensed mainly from a description by Mr. G. W. Rafter in the report of the N. Y. Commissioners of Fisheries, Game and Forests for the year 1899. A more complete description was published in Engineering News May 18, 1899.

In 1897, the Indian River Co., a corporation composed of owners and users of water power on the Hudson river, was organized to develop the storage of Indian Lake to full capacity in order to help out the low water flow of the Hudson river.

A masonry dam was constructed havings its stone spillway crest at elevation 1,650 above sea, twenty-three feet higher than the crest of the old lumbermen's dam at this point, which had fallen into decay, and which old dam flowed the water ten feet above its natural level. Thus the new construction raises the water about thirty-three feet above the surface of the original lake, which was about two miles in length and about one-third of a mile in width at the broadest portion.

The reservoir thus enlarged has an area of about 5,000 acres at the spillway level and is about thirteen miles long.

It is of interest to note that when the first lumberman's dam six feet in height was built here in 1845, the timber was left standing upon the areas flooded, as was also done when later the original dam was rebuilt and raised to a total height of ten feet, for log driving purposes. This flooded timber died and remained standing for many years a serious blot on the landscape. After

about forty years from the original flooding, the great bulk of it had fallen down, and since that time and aside from the few scattering stubs here and there, the old reservoir *when full* is said to have presented the appearance of a fine natural lake.

The storage of the ten foot timber dam was estimated at 800 million cubic feet, and that of the new masonry dam up to the spillway level is estimated at 4,468 million cubic feet, or if flash boards two feet in height are admitted, a storage may be expected of roundly five billion cubic feet.

The State acting through the Forest Preserve Board took a strong interest in the construction of this new dam, which with the clearing of the trees from the flowed land, is stated to have cost about $100,000, and at an expense of $164,000 the State acquired, largely from parties interested in the building of the dam, about 42,000 acres of land from which the merchantable lumber had been cut, adjacent to and including Indian Lake, to form a portion of the Adirondack Park, provided for under legislative acts of 1893, 1897 and 1898. A statement of the conditions leading to this purchase is presented in the report of the Forest Preserve Board, made to the Governor on January 29, 1898.

It was stated that if the old wooden dam was allowed to decay, "the water would be drawn to its former level, reducing the lake to one-third its present size and leaving miles of devastated flats," and the action of the State in this purchase "was based upon a consideration of the advantages gained in thus not only preventing the destruction of Indian Lake in its beauty, but also in preserving it as a vast reservoir for supplying the Champlain canal and improving the navigation of the Hudson river. It is to be noted in this connection that the control of the waters has been thus secured to the State rather than left in the hands of private parties."

The State has from time immemorial retained ownership in the flow of the Hudson sufficient for the needs of the canal. The real benefits of the enlarged Indian Lake have accrued so far as I can see, solely to the water powers and in such very slight and almost inappreciable extra depth of water for navigation near Albany as may occur, while the release of this storage is going on. While the nominal control rests in the State, the actual regulation of

the sluices is understood to be done by an employee of the water power owners.

The specifications for clearing the reservoir margin provided that "all timber and brush of every sort, kind and description now standing on the banks of Indian river or Indian lake above the site of the proposed dam and between the present margins of the said river and a line above the proposed flow line, should be cut *to within two or three feet of* the ground and thoroughly burned," etc.

It is of interest to note that Mr. Rafter had recommended in the report of 1895 that all standing timber, undergrowth and brush be "*cut down to the ground* and burned."

It was found extremely difficult to burn the bodies of the trees and so it is said it was concluded not to attempt to burn the heavy logs, but so far as possible to float them out after the reservoir had become full.

It is stated afterward by Mr. Rafter that "no such extended clearing of reservoir margin in the forest area had previously been carried out in the State, and that every attempt had been made to have the clearing at Indian Lake well done, and that the non-completion of the burning during 1898 was due entirely to constant rains during the months of October and November."

It is stated p. 398, the contract price for cutting and burning was $13.50 per acre, which was rather low. The soft wood of commercial sizes had long ago been closely cut and rafted out, and the larger trees left were chiefly hardwood, which does not float or cannot be rafted downstream.

The method finally adopted was, as described by Mr. R. E. Horton, Asst. Engr., that "after cutting into proper lengths for burning the brush, etc., the large trunks are to be left until after the reservoir is completed and filled, after which the hardwood and softwood logs will separate, the former remaining at the bottom and out of the way, while the floating softwood will be rafted down the lake and sluiced through the dam in the same manner as logs intended for lumber, after which it may be allowed to take care of itself as driftwood in the stream," to later be caught in the log boom above Glens Falls and cut into fire wood for the market.

Much difficulty was found in the burning on the narrow margins without permitting the fire to work up the slope and back into the forest, particularly in cases where the spruce duff covered the ground sometimes to a depth of several feet. The plowing of furrows as specified for fire guards outside the limits was in many places inapplicable because of boulders and rough ground, and where the duff and vegetable mold was thick, a space had to be cleared by means of grub hoes for a width of at least thirty-three feet back from the standing timber and the brush piled for burning, back of this line.

I have quoted thus extensively from the reports of the engineers under whom the Indian Lake reservoir was constructed, because of having myself inspected the margins of this reservoir during the past summer in company with the members of your board, when I found the presence of stumps left by this cutting at two or three feet above the suface of the ground so unsightly and so dangerous to pleasure boating when the lake is partially drawn (as it naturally would be during August and September) that it appears important to emphasize as strongly as possible that a more exacting specification should be made, and lived up to, in the case of other storage reservoirs permitted within the Adirondack Park, or wherever constructed subject to State control.

STORAGE DRAFT FROM INDIAN LAKE.

The records of the daily height in Indian Lake above the bottom of the sluice ways, have been presented from year to year in the reports of the State Engineer and in the Water Supply papers of the U. S. Geological Survey, but no record of outflow has been published.

In a published description of the dam and sluices, it is stated that the preliminary estimate of discharge for the two gates from a full reservoir was 1,400 cubic feet per second, but that it was not expected to draw more than 1,000 cubic feet per second.

In analyzing the yield of the several portions of the Hudson drainage, it is important to know what portion of the flow is from time to time coming from this Indian Lake storage.

We find by methods as described later, that the actual rate of draft seldom exceeds 750 and probably averages about 600 feet for a total of somewhat more than 100 days per year, and that it is

drawn on nearly as often in midwinter as in midsummer, and the record of what has actually happened here is of interest as indicating the probable time and extent of drawing future reservoirs built solely for storage purposes and for showing to what extent they would serve in flood control.

I have, therefore, attempted approximate preliminary computation from such data as were available, and finding that the data on file were contradictory and incomplete, have had Mr. Geo. G. Shedd, C. E., visit the lake to take such measurements of the parts affecting the discharge as could be made in midwinter, with the lake full.

The published statements of storage capacity of Indian Lake at various heights are incomplete and perhaps rest on crude measurements. An accurate contour map of the bed on large scale should be made and a table of capacity at various depths prepared. A survey on the ice with soundings at frequent intervals could be cheaply made. We did not have time to attempt this, but have relied on the few statements of capacity at various levels found scattered in various reports and have drawn a diagram from them for present purposes.

Mr. Shedd finds that the elevations of bottom of discharge openings, corresponding to the elevations marked on the upper portion of the gage staff now in use, are as follows:

Stone crest of spillway (total net length 88.5 ft.)	33.23	± 0.15
Average crest of flashboards 6 inches wide four bays	33.75	± 0.15
Average crest of flashboards 12 inches wide one bay	34.20	± 0.15
Crest of small logway 16.0 ft. wide	31.76	
Crest of large logway 15.7 ft. wide	23.41	
Top of main masonry dam	40.55	

No record of height of flashboards is kept. These are changed occasionally. Those now on are of irregular width.

The spillway contains two bays less length than shown on plans on file. The bays are of length averaging 17.70 feet each.

The two iron sluice gates, set new last year, have their center at zero of the upper portion of the gage staff, as nearly as could be determined under the full reservoirs and inability to close one of the guard gates found at the time of Mr. Shedd's visit, so the published lake level gives the static head on center of main sluice gate very nearly.

The top portion of present staff is legible and has metal foot figures and metal staples for the inch marks. These are said to have been set several years ago by Mr. R. E. Horton. The middle and lower portions of the staff are said to have become illegible so that when lake level is below thirty-three feet, measurements are now made with fragments of cloth tape, measuring down from top of gage, in a way liable to introduce occasional error. The recorded rise of about seven feet in one day on September 30, 1904, is plainly a mistake, which from the daily course of the records must have continued over a long period.

The metal figures are understood to have not been attached to gage below thirty-three, because of height of water at the time, and there are grounds for thinking there may have been some change made from the original heights, at date unknown, because it is stated repeatedly in the State

Engineer's reports and the U. S. Water Supply papers (for example, in the State Engineer's Report of 1902 and 1905 and the Water Supply paper No. 97), that zero of gage was set at bottom of the five-foot discharge tunnels.

Our measurements show that the bottom of the gate well is 39.58 feet below the present thirty-six foot mark of the gage, and since the caretaker states that the bottom of well is one foot below bottom of gate, it appears certain that, as the gage now stands, the published statement is wrong.

It is difficult to compute precisely the discharge of these sluice gates from the given head in the lake and the given height of gate opening, because of the great loss of head through the two guard gates that supply the gate chamber leading to each one of the two sluice gates and their liability to become obstructed by snags. We found this loss to be 13.3 feet when the two guard gates to one sluice chamber were wide open, and the one sluice gate was wide open, the reservoir being at gage height 35.0.

From what could be learned, it appears that any estimate of discharge through sluice gates prior to 1907 will be of uncertain precision because of the clogging of the guard gates or their screens with drift wood. Moreover, the hoist on one was defective and one guard gate on well B was kept closed for a long period, of which we find no record. The operation of the iron sluice gates was so difficult that both were replaced at low water in winter of 1906–7.

To determine the loss of head through the upstream gates or guard gates, of which there are two, each about 3 ft. x 5 ft., to each of the separate wells for the two 5-foot sluice gates, measurements were made by opening sluice gate B to various heights and noting gage reading in lake and the height in the well. The results are given in table following.

Because of the inability at this time to close one of the guard gates, it was not possible to drain the well and enter it for precise measurements of aperture of either guard gate or sluice gates, nor was it practicable to make precise measurements of elevation of sluice ways relative to scale height. The standard bench mark was inaccessible under snow and ice.

EXPERIMENTS ON LOSS OF HEAD THROUGH GUARD GATES AT INDIAN LAKE SLUICES.

HEIGHT IN LAKE BY SCALE.	Sluice gate, height.	Observed loss through two guard gates wide open.	Computed discharge of sluice gate.	Resulting co-efficient discharge of guard gate and screen.
Feet.	Feet.	Feet Head.	Cu. Ft. Sec.	
35.0	0.5	0.15	70	.....
35.0	1.0	.95	150	.64
35.0	1.5	2.15	220	.63
35.0	2.0	3.45	290	.65
35.0	2.5	6.85	370	.59
35.0	3.0	8.85	430	.60
35.0	3.5	10.45	475	.61
35.0	4.0	11.50	515	.62
35.0	4.5	12.85	535	.63
35.0	4.8	13.35	550	.63

The values in the last column are about what might be expected for the coefficient of a rectangular gate opening. Therefore, the screens were probably clear.

From the recent topographic maps of the U. S. Geological Survey, we find the drainage area, including the lake, is 131 square miles instead of the 146 that has been published.

Calling total capacity of Indian Lake 4.7 billion cubic feet, this would supply for 100 days $\frac{4{,}700{,}000{,}000}{86{,}400 \times 100} = 544$ cubic feet per second in addition to the inflow meanwhile.

Calling the evaporation loss 5 inches in each of the months July and August, this, on an area of 3,500 acres as partly drawn, would be equivalent to $\frac{3{,}500 \times 43{,}560 \times 5}{12 \times 30 \times 86{,}400} = 24$ cu. ft. sec., but the inflow from 131 sq. miles at, say, 0.18 cu. ft. sec. per sq. mile in any but the most extreme drought would be 24 cu. ft. sec. and would keep the lake from lowering by evaporation.

The full contents of the reservoir, if 4.7 billion gallons, would be filled by a run-off equivalent to 15.7 inches in depth, from the watershed of 131 sq. miles.

The daily heights in the lake as published in the State Engineer's report have been plotted in a diagram on plate 5 and on the same sheet is given such information as we have been able to work out regarding the times and rates of storage draft in each of the recent years.

On the same sheet, the roughly approximate diagrams that we have used for computing the discharge of sluices and logways are presented for use until something better is available and a capacity curve of the lake for various gage heights is plotted on same sheet, prepared from such few statements of volume at given heights as could be found published.

The computations of outflow have been made in two ways, and the results agree in a general way in showing that a discharge of not far from 600 cu. ft. per second is commonly maintained for about three to four months in all, or from 90 to 130 days, and it is of particularlar interest to note that this storage is as commonly drawn upon in January and February as in midsummer.

LUMBERMEN'S STORAGE.

It should be remembered in studying records of low water gagings of the Hudson, that there is still more or less control of sundry lakes by lumberman's dams for purpose of log driving, and although according to the topographic map the

All of these sources of information, the Mechanicville gagings, the Fort Edward gagings, the rainfall studies and the comparison of yield per square mile with the yield of the Croton and other drainage areas from which the daily flow has long been gaged, are found to confirm one another remarkably well, as will appear in the following pages, and as a result of the work of the past few months in studying the various records, we can now predict the discharge available under various conditions from the proposed Sacandaga reservoir accurately enough for all practical purposes, and *the present estimates of quantity of power available rest on a much more full and reliable foundation than is ordinarily available when planning a great power development.*

The sources of data and the results concerning this available Sacandaga flow will next be described, with only such fullness as is needed to make clear the reliability of the evidence and the methods of estimating.

GAGINGS OF HUDSON AT MECHANICVILLE.

The records which I have used for the monthly flow of the Hudson and its tributaries at Mechanicville, Ft. Edward and Warrensburg and Buskirk, are found in the annual reports of the State Engineer and in various water supply papers of the U. S. Geological Survey and in Rafter's Hydrology of New York and in advance copies of the records of the past year kindly furnished me by the U. S. Geological Survey, by the State Engineer and by Mr. E. P. Bloss, the Engineer in charge of the water power of the West Virginia Pulp and Paper Co. at Mechanicville.

From October 1, 1887, to November, 1897, the estimates of Hudson flow at Mechanicville were computed under the supervision of Mr. George W. Rafter from notes placed at his disposal by the mill owners. For later years, the records and estimates have been made under supervision of Mr. Bloss, Engineer of the West Virginia Pulp and Paper Co., the present owner of this power site and paper mill.

The daily gaging comprises an estimate of the flow passing over the crest of the stone dam from gage readings said to be taken twice each day and an estimate of the quantity passing through each of the numerous turbines of the adjacent paper mill, made up from a record of the number of hours run by each, the head acting on the turbine for that day and a statement of the discharge of a turbine of this size under this head, given by the manufacturer of the turbines. Most, if not all, of these turbines are fortunately of models and sizes which have been accurately tested in the Holyoke testing flume.

CHECK MEASUREMENTS ON TURBINE FLOW AT MECHANICVILLE.

As confirmation of accuracy of these turbine discharge tables for wheels long in use, it is stated that a test made at the mill by Mr. Bloss, Engineer of the company, of a twenty-nine inch Hercules wheel in use eight years, showed the actual discharge, when run at speed of greatest efficiency, to be substantially as given in the manufacturer's tables.

NOTE.—See report New York State Engineer for 1905, page 577; see Rafter Hydrology of New York, 1905, page 365; see also reports of U. S. Geological Survey Water Supply Papers No. 202, page 19; No. 166, page 19; No. 125, page 23; No. 97, page 222; No. 82 page 102; No. 65, page 49; No. 35, page 24.

For further confirmation of the accuracy of the turbine discharge tables, several check gagings by current meter have been made at the Toll Bridge a short distance down stream from the paper mill at times when no water was passing over the dam, as follows:

On page 581, New York State Engineer's report for 1905, it is stated that October 10, 1905, the discharge by regular mill record was 5,181 cubic feet per second, while discharge by current meter gaging was 4,900 cubic feet per second. This comparison gives an excess by turbine record of about 5 per cent.

On October 20, 1900, another comparison was made, which is reported in U. S. Geological Survey Water Supply Paper No. 65 for 1901. The check measurement by current meter at Toll Bridge showed 1,871 cubic feet, but this measurement was not regarded as very reliable because of slack water. Meanwhile the discharge computed from the turbine records was 1,977 cubic feet, or about 5 per cent. greater.

It is desirable that further test measurements of this character be made in time of drought, for on *certain occasions the minimum flow in time of drought given in the Mechanicville records is remarkably large* and much larger than the estimates already quoted from the Census report on page 65.

Moreover, on trying to analyze the sources of the large flow recorded at Mechanicville in the last of August and the first of September, 1907, in view of our gagings on the tributaries and our estimates of Indian lake discharge, I am unable to find where so large a flow all came from. Certain records made at the electric power stations at Spier Falls and Mechanicville also show lower flows in the drought of 1907 than are given by the standard records from the paper mill.

ACCURACY OF MEASUREMENTS OVER MECHANICVILLE DAM.

The present conditions for accuracy in measuring the flow *over the dam* at Mechanicville are excellent. The dam is of masonry on a ledge foundation and has a rounded, level concrete crest, added in the summer of 1904, and new discharge tables for this crest have been prepared based upon experiments made at the Hydraulic Laboratory of Cornell University, (it is not stated if the model was precisely similar).

Mr. C. E. Parsons, Chief Engineer, Hudson River Electric Power Co., has stated to me that he has repeatedly looked into the matter of the gagings at Mechanicville and regards them as very accurate. He further states his belief that the crests of the river dams at Mechanicville and at Fort Edward are seldom obstructed by driftwood so as to interfere with accuracy of gaging, and that he has found the Mechanicville crest particularly free from obstruction of that kind.

Prior to the summer of 1904, the Mechanicville dam had a flat masonry crest about seven of eight feet in width, inclining downward upstream on a slope of about one in eight, as shown in the sketch in N. Y. Hydrology 1905, page 366.

It is stated in the published records referred to above, that for the years from 1899 to 1904 the discharge was computed by the Francis dam formula. This formula would apply accurately only at those times when the flash boards were removed, which presumably is the case only in time of flood, but it is stated that the same formula was used at times when flash boards

were in place. When the flash boards were in perfect condition, this would give a slight overestimate which, however, would be offset by the leakage of the flash boards at other times and by their being occasionally somewhat bent over.

For the twelve years 1888-1899, it is stated that during the period when flash boards were off the flow over the dam was computed by the Mullen formula of the East Indian engineers. I doubt if this formula applied so accurately as the Francis dam formula. For that part of the year when flash boards were in use, Mr. Rafter used the Francis formula for a sharp edged weir, which is doubtless the most accurate of any that could be applied to this condition.

Comparing the mean monthly flow for the years 1898 and 1899 as computed under supervision of Mr. Rafter from the East Indian formula and the weir formula as just described, with the results of computations made for the same years under Mr. Bloss day by day with the Francis dam formula, the discrepancy in monthly means seldom exceeds 5 per cent. in any one month, and taking the whole year through, the flow as computed by the East Indian formula with flash boards, averages about 2 per cent. greater than for the computation by the Francis dam formula.

During the seventeen years of gaging prior to the summer of 1904, there is perhaps a little occasional uncertainty about leakage through the flash boards and probably the actual flow would therefore equal that recorded, notwithstanding the difference in formulas.

Since in 1904 when the flash boards were abandoned due to the addition of the rounded concrete crest, gaging of the portion of the river discharge that flows over the dam is presumably very accurate.

The uncertainties and differences due to the different formulas used in the previous years are less than the probable errors introduced by the turbine measurement. These errors may be due to turbines being not always run at full gate, and due to the leakage through those turbines that are shut down. There is doubtless at times some retardation of flow due to ice or other obstruction upon the forebay screens or in the turbines.

The writer happens to have had about ten years' experience in making daily estimates of river flow under somewhat similar circumstances, and where great pains were taken to confirm the results of turbine measurement by independent methods of gaging, and from this experience, although no proof can be given as to the precise margin of error, he inclines to the opinion that because of uncertainties about the turbines and flash boards, although occasional errors would balance, the precision of measurement attained in the Mechanicville gaging as a whole, through turbines and over dam, cannot be relied on as closer than 5 per cent. for the average of, say, a three year term as used in the mass curve.

For the average of a single week, errors of 10 per cent. are not improbable, particularly in the period prior to the summer of 1894, at which time the masonry crest replaced the flashboards on the dam, and for single days there is a possibility of still larger error. It is to be borne in mind that the two check measurements by current meter found the method by turbine measurement 5 per cent. in excess of the current meter. For these reasons, I have been conservative in the final estimate of Sacandaga power and made what I believe due allowance for all margin of uncertainty in calling the mean flow available from Sacandaga reservoir 1,700 cubic feet

per second; for this figure in effect discounts 15 per cent. from the quantity that is most probable on the face of the returns after studying the greater rainfall on the Sacandaga.

INTERPOLATIONS.

No records are found published for the flow at Mechanicville in the month of January, 1902, or months of November and December, 1905. To complete our record for the mass curve computation, an interpolation based upon the Fort Edward record has been used in these places, making due allowance for the difference in drainage areas. Similarly for July, August and October, 1904, while the record at Mechanicville was interrupted during the building of a new crest on the dam, the vacancies have been supplied by the use of the Fort Edwards records.

DIVERSION FOR THE CHAMPLAIN CANAL.

The published record of Hudson river flows at Fort Edward and Mechanicville requires a small correction to compensate for the diversion of water for the supply of the Champlain canal, and since the records previously published in the State Engineer's reports did not make the amount of this correction as definite as desired, a special investigation was made at my request under the supervision of Mr. H. K. Barrows of the U. S. Geological Survey, from which he concludes that during the season while the canals are in use there should be added 200 cubic feet to the Mechanicville record and 180 second feet to the Fort Edward record. This accords well with the result of sundry previous but less complete gagings.

These corrections of 180 and 200 cubic feet per second are equivalent to additions of .07 inches depth of monthly run-off on the watershed tributary to Fort Edward and to .05 inches depth of monthly run-off from the watershed above Mechanicville while the canals are in use.

The length of the navigation season according to the table given in page 1,060 of the history of the New York canals, published by the State Engineer in 1905, during the period covered by the gagings at Mechanicville and Fort Edward, has averaged seven months, opening about May 1st and closing about December 1st. These corrections have therefore been applied during the months from May to November inclusive, and are included in the tables on pages 104 and 105 upon which the mass curves of Diagram No. 2 for computing the Sacandaga storage are based.

The total diversion into the Champlain Feeder canal from the Feeder dam above Glens Falls, in recent years probably has been about 220 cubic feet per second, being now much less than in former years when as high as 383 second feet have been measured (October 8, 1895).

This lessening of the diversion at the State feeder dam is due to repairs and to stoppage of the leaks along the course of the feeder canal through the town of Glens Falls.

This feeder canal supplies the summit level of the Champlain canal, and therefore a portion of the water flows northward into Lake Champlain, and a portion flows southward, returning into the Hudson where the canal enters the river for the boats to cross it above the Saratoga dam.

A second diversion from the Hudson occurs into the canal leading southward from the Saratoga dam, and a gaging made in the canal as nearly

opposite as practicable to the gaging station at Mechanicville shows this to average about 110 second feet, which added to the 90 second feet diverted northward into Lake Champlain makes the 200 second feet of diversion that must be added to the Mechanicville gaging station when reckoning the yield per square mile from its watershed.

Of this 220 second feet now diverted from the Hudson, about 90 second feet flows northward into Lake Champlain, and although nearly all of the remaining 130 feet ultimately reaches the Hudson, some of it by leakage above Fort Edward, the most of it does not get back into the Hudson until some miles below Fort Edward where the canal crosses the river. The addition necessary to compensate the Fort Edward gagings so they will show the entire yield of the drainage area is found by measurement to be 180 cubic feet per second.

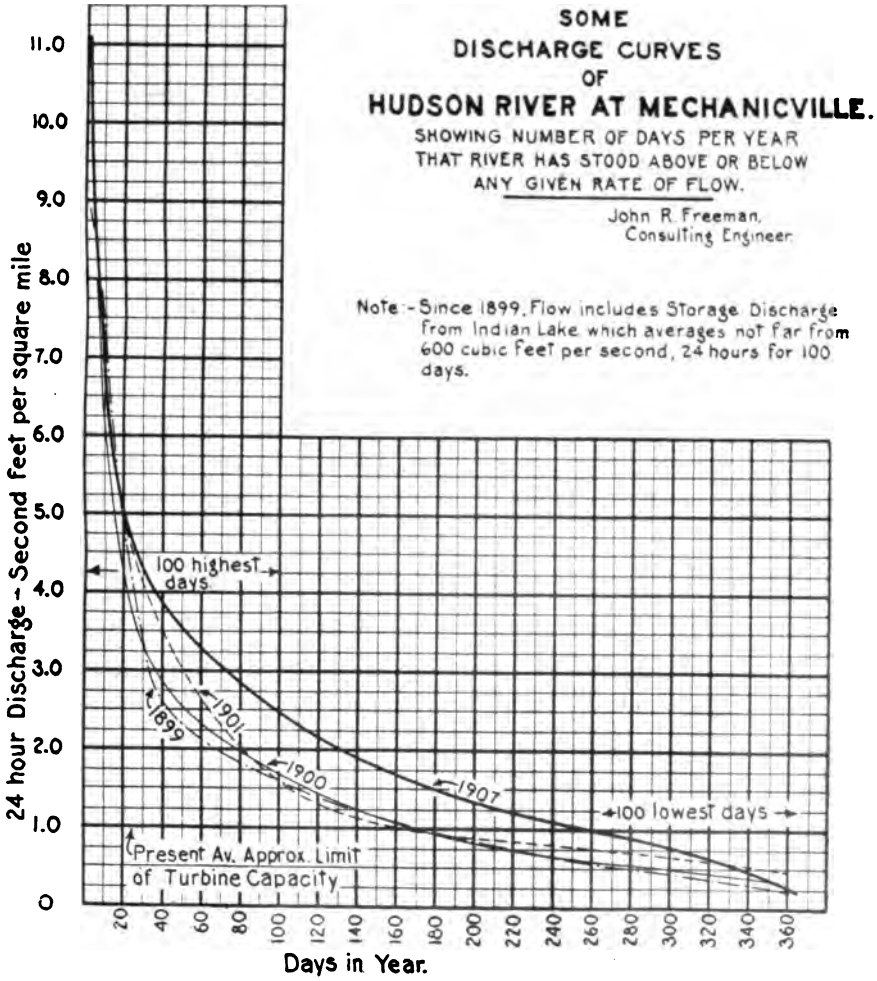
RUNOFF OF HUDSON RIVER AT MECHANICVILLE FOR THE WATER YEARS 1888–1907, INCLUSIVE.

(*In inches depth over entire catchment area.*)

(*Catchment area* — 4,500 *square miles.*)

Corrected for canal diversion, May to November, inclusive.

MONTH.	1888.	1889.	1890.	1891.	1892.	1893.	1894.
December	2.05	2.57	3.39	0.83	2.27	1.03	1.85
January	1.62	2.81	2.89	2.12	4.83	0.82	1.73
February	0.89	0.88	1.83	2.70	2.22	1.09	1.12
March	1.75	2.12	2.85	4.55	2.80	2.11	3.78
April	5.26	3.39	3.73	4.97	5.35	4.44	2.76
May	5.54	2.32	4.64	1.47	5.08	5.76	1.99
Storage period	17.11	14.09	19.33	16.64	22.55	15.25	13.23
June	1.27	1.75	1.88	0.84	3.13	1.24	1.81
July	0.44	1.52	0.55	0.65	2.43	0.70	0.86
August	0.49	1.14	0.57	0.73	1.46	1.33	0.68
Growing period	2.20	4.41	3.00	2.22	7.02	3.27	3.35
September	0.76	0.54	2.24	0.56	1.15	1.75	0.52
October	1.23	1.01	2.41	0.43	0.77	1.04	0.99
November	2.69	2.01	2.31	1.06	1.94	0.95	1.63
Replenishing period.	4.68	3.56	6.96	2.05	3.86	3.74	3.14
Yearly total	23.99	22.06	29.29	20.91	33.43	22.26	19.72


SOME
DISCHARGE CURVES
OF
HUDSON RIVER AT MECHANICVILLE.
SHOWING NUMBER OF DAYS PER YEAR
THAT RIVER HAS STOOD ABOVE OR BELOW
ANY GIVEN RATE OF FLOW.
John R. Freeman,
Consulting Engineer.
Note:-Since 1899, Flow includes Storage Discharge from Indian Lake which averages not far from 600 cubic feet per second, 24 hours for 100 days.
24 hour Discharge - Second feet per square mile
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
100 highest days
1899
1901
1900
1907
100 lowest days
Present Av. Approx. Limit of Turbine Capacity
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Days in Year.

RUNOFF OF HUDSON RIVER AT MECHANICVILLE FOR THE WATER YEARS 1888–1907, INCLUSIVE.

(In inches)

(Catchment area — 4,500 square miles)

Corrected for canal diversion, May to November, inclusive.

MONTH.	1895.	1896.	1897.	1898.	1899.	1900.	1901.
December	1.12	2.79	1.77	3.67	1.40	1.86	1.36
January	0.99	1.74	1.03	1.97	1.71	1.50	0.79
February	0.82	1.12	0.90	1.56	1.22	2.88	0.67
March	1.08	3.49	3.13	5.18	2.47	1.98	2.00
April	5.91	6.20	4.73	3.40	5.86	5.60	7.03
May	1.81	1.23	3.09	2.88	2.54	2.35	3.04
Storage period	11.73	16.57	14.65	18.66	15.20	16.17	14.89
June	0.75	1.23	2.99	1.35	0.70	1.06	1.98
July	0.71	0.77	2.79	0.69	0.67	0.65	0.96
August	1.05	0.68	2.16	1.35	0.41	0.74	1.23
Growing period	2.51	2.68	7.94	3.39	1.78	2.45	4.17
September	0.70	0.76	0.73	1.01	0.56	0.52	1.05
October	0.74	1.10	0.70	2.07	0.72	0.59	1.13
November	2.13	2.87	2.52	2.34	1.63	1.29	0.97
Replenishing period	3.57	4.73	3.95	5.42	2.91	2.40	3.15
Yearly total	17.81	23.98	26.54	27.47	19.89	21.02	22.21

MONTH.	1902.	1903.	1904.	1905.	1906.	1907.*
December	2.16	2.11	1.36	1.00	(2.01)	1.24
January	(0.99)	1.80	1.49	1.56	2.39	2.59
February	1.58	2.28	1.64	0.82	1.77	1.02
March	6.36	7.92	2.83	2.41	2.31	2.41
April	3.77	3.47	5.14	5.64	5.11	4.16
May	2.08	0.95	3.46	2.14	3.49	3.55
Storage period	16.94	18.53	15.92	13.57	17.08	14.97
June	1.61	2.15	1.73	2.39	2.35	1.54
July	2.33	1.30	(0.96)	1.81	1.53	1.05
August	1.66	1.56	(1.26)	1.49	0.94	0.50
Growing period	5.60	5.01	3.95	5.69	4.82	3.09
September	0.95	1.07	1.70	3.03	0.81	1.34
October	1.81	2.64	(2.70)	1.60	0.91	2.46
November	1.63	1.48	1.20	(1.94)	1.32	3.58
Replenishing period	4.39	5.19	5.60	6.57	3.04	7.38
Yearly total	26.93	28.73	25.47	25.83	24.94	25.44

* From advance copies of daily record, kindly furnished by Mr. R. P. Bloss C. E.

ACCURACY OF FORT EDWARD GAGINGS.

The conditions for accurate gaging at Fort Edward are decidedly less favorable than at Mechanicville. The methods followed are much the same at the two places, but at Fort Edward the number of turbines is larger and their uncertainties correspondingly greater, and it is possible that the making of the record is less closely supervised.

The main source of uncertainty in the Fort Edward gagings affects the results only in time of high water. This is due to a flood spillway whose crest is about level with the top of the flash boards, and which is of such irregular form that it caused uncertainty in the computation of the flow through it.

In New York Hydrology, page 375, Mr. Rafter says of the measurement through this flood spillway, that the computations may at times of high water be as much as 25 per cent. in error. (This percentage is understood to apply only to the portion flowing through the flood spillway and not to the larger portion over the main dam 587.6 feet long), and that for a number of years, he was unwilling to publish the record, but has since reviewed it, recomputing a portion.

Mr. H. K. Barrows, Hydrographer, U. S. G. S., considers that the gaging records at Fort Edward are probably from 5 per cent. to 10 per cent. in error at times, owing to the large number of turbines used in the record and the poor condition of the dam for gaging, especially at its right end, but also states that the Mechanicville records are probably accurate inside of 5 per cent., since the Mechanicville dam is in excellent condition, and the records of flow are closely looked after by a competent engineer.

In Water Supply Paper 166, page 18, it is stated that the drainage area above the Fort Edward dam is 2,800 square miles, that the timber dam rests on a slate ledge foundation and has but little leakage, that the crest is straight and nearly level and 287.6 feet long. In other Water Supply papers, it is stated that new and accurate profiles of the crest were made in 1903 and again in 1906, and used in determining the discharge. A photograph of this dam is shown in New York Hydrology, page 628.

In Water Supply Paper No. 65, page 48, it is stated that a record is kept of the height of the flash boards and of the heights of their setting and removal, and that the flow at that time, 1901, was computed by the Mullen, or East Indian Engineers formula.

In Water Supply Paper 125, for 1904, it is stated that for those periods while the flash boards are off, the discharge has in more recent years been computed in accordance with experiments made by the Geological Survey upon a model dam of this form. With flash boards on, the discharge is computed according to the Francis thin edged weir formula.

In the dry season, very little water passes over the dam, all or nearly all passing through the sixty-two turbines in the adjacent paper mill.

These water wheels are stated to be nearly all of modern types which have been tested at the Holyoke flume. A record is kept of the number of hours run by each turbine and of the working head, which is usually nineteen feet.

Check measurements have occasionally been made by current meter at a bridge downstream from the Fort Edward water power. In Water Supply Paper U. S. G. S., page 48, it is stated that check measurement made July 26, 1900, by current meter at bridge below dam, showed 2,704 second feet, while the computed discharge from turbine diagrams varied from 2,420 to 2,720 cubic feet, the average by the turbine diagrams thus being 6 per cent. less than by the current meter gaging.

There are a few obvious errors in the Fort Edward record, viz., the monthly flows for December 1897, and December 1898. For these periods, interpolations based on the Mechanicville gagings have been used.

RUN-OFF OF HUDSON RIVER AT FORT EDWARD FOR THE WATER YEARS 1896–1907, INCLUSIVE.

(*In inches depth over catchment area.*)

(*Catchment area* — 2,800 *square miles*)

Corrected for canal diversion, May to November, inclusive.

MONTH.	1896.	1897.	1898.	1899.	1900.	1901.
December	1.97	2.61	1.12	(1.40)	2.12	2.19
January	1.40	0.65	1.51	1.95	1.32	0.75
February	0.96	0.64	5.75	0.70	2.64	0.57
March	2.62	2.32	4.11	2.05	1.61	1.41
April	6.46	5.05	2.93	6.69	6.74	8.46
May	1.68	3.87	3.00	3.90	2.68	3.52
Storage period	15.09	15.14	18.42	16.67	17.11	16.90
June	1.55	3.95	1.47	0.70	1.20	2.57
July	1.17	3.67	0.63	0.54	0.58	0.97
August	0.61	2.82	1.25	0.37	0.75	1.10
Growing period	3.33	10.44	3.35	1.61	2.53	4.64
September	0.70	0.65	0.87	0.60	0.51	1.06
October	1.45	0.64	1.45	0.49	0.57	1.17
November	3.56	3.07	2.18	2.10	2.09	0.92
Replenishing period	5.71	4.36	4.50	3.10	3.17	3.15
Yearly total	24.13	29.94	26.27	21.49	22.81	24.69

MONTH.	1902.	1903.	1904.	1905.	1906.	1907.
December	1.96	2.03	1.46	0.93	2.01	1.42
January	0.99	1.53	2.02	1.17	3.12	3.13
February	0.82	1.95	1.27	0.83	1.96	1.27
March	5.47	7.02	2.88	1.83	2.56	2.79
April	2.81	2.54	6.38	7.08	6.49	5.35
May	2.00	1.12	4.29	2.51	4.63	4.66
Storage period	14.05	16.19	18.30	14.35	20.77	18.62
June	1.78	2.94	2.10	3.66	2.94	1.76
July	3.03	1.95	0.98	2.75	2.15	1.18
August	2.02	1.91	1.28	1.59	1.22	0.77
Growing period	6.83	6.80	4.36	8.00	6.31	3.71
September	1.05	1.30	1.17	3.59	1.25	1.48
October	2.05	2.82	2.72	1.86	1.36	3.08
November	2.16	1.55	1.21	1.94	1.84	4.15
Replenishing period	5.26	5.67	5.10	7.39	4.45	8.71
Yearly total	26.14	28.66	27.76	29.74	31.53	31.04

GAGINGS OF SCHROON RIVER AT WARRENSBURG.

There is available a record of the flow of the Schroon for a few years, which is probably much less precise than that at Mechanicville and somewhat less precise than the Fort Edward record, but since the Schroon is one of the largest tributaries of the Hudson and comes from a watershed of somewhat different characteristics, where according to the isohyetal maps the rainfall is somewhat less than for the Sacandaga or the central and more elevated portions of the Adirondack plateau, it has appeared wise to make the best possible comparison of the Schroon and Fort Edward gagings as one more check upon our estimates of the Sacandaga yield.

The gaging of the flow of the Schroon is said to have been begun in November 1895, in connection with studies for Adirondack storage, reported upon in the N. Y. State Engineer's report for that year.

The State Engineer's report for 1901, page 541, presents records of daily flow from November 1895 to December 1901, and gives a description of the gagings, substantially the same as that found in U. S. G. S. Water Supply Paper No. 65, page 45.

In U. S. G. S. Water Supply Paper No. 82, page 100, the daily flows are given for January, February, and March, 1902, and it is stated that owing to a change in management, the data for the remainder of the year were not available at time of publication. Water Supply Paper No. 97, page 222, states that records were maintained during 1903 under the supervision of R. E. Horton, Hydrographer, but publication was withheld awaiting additional data to confirm results.

The original record is understood to consist of a single daily measurement of depth flowing over the dam of the pulp mill at Warrensburg and a daily record of the hours run by the turbines.

The mill dam was of timber, was built in 1893, and stated in Water Supply Paper No. 35, page 58, to then have been "tight as any of its kind,"

but Mr. W. Greenalch, then assistant to Mr. Rafter, considered the estimates of flow at Warrensburg vitiated by the leakage through this dam and by the changes of the flash boards upon it. It appears probable that this leakage increased from year to year.

Mr. G. W. Rafter in New York Hydrology 1905, pages 400–403 gives a summary of the records for the Schroon and states that at the time of his inspection in October, 1895, with the pulp mill shut down and the Starbuckville dam tightly closed, the bed of Schroon river below Warrensburg was nearly dry, the flow not exceeding one to two cubic feet per second. He states that reports indicate that the leakage at a later date might be anywhere from 30 to 50 cubic feet per second.

In 1899, the average low water flow of the Schroon river at Warrensburg was estimated at 150 cubic feet per second, this being the assumed leakage of the Starbuckville dam at that time.

In time of low water, the mill was shut down, and whatever flow was not held back by the storage dam which controls the outlet of Schroon Lake at Starbuckville, came down the river and leaked through the Warrensburg dam. No daily record of flow was kept when the mill was not running.

The leakage of its dam, flash boards and flume on August 9, 1900, measured at a point one-half mile down stream from the dam in the open channel by current meter, was found to be 285 second feet.

This quantity was taken as fairly representative of the average low water flow and leakage in 1901, when making up the estimates published in the reports of the U. S. Geological Survey and the reports of the N. Y. State Engineer, which I have used.

For computing flows over the dam when flash boards are on, the Francis weir formula was used. When there are no flash boards, a formula derived from the Cornell University experiments on a model of similar shape is used.

The pulp mill ran twenty-four hours per day for so much of the year as there was water to supply it, and being the only water power upon the Schroon, its owners controlled the flow for the benefit of the pulp mill by a dam on the outlet of Schroon lake, by which it is said water stored to a depth of from four to five feet on an area variously stated at from seven to nine square miles, is let down as required for use during the summer months.

In comparing the curves for Schroon yield with those of the main river, it should therefore be kept in mind that the Schroon has a flow regulated by storage, while the only other storage of which the main river has the benefit is that of Indian lake and perhaps a few lumbermen's dams.

While it is plain from the above description that these measurements of daily or monthly flow on the Schroon are not precise, it has been thought worth while to consider them, but only as checks, in relation to the estimates of Sacandaga yield deduced from the Mechanicville gagings.

GAGINGS OF HOOSIC RIVER AT BUSKIRK.

A study of these gagings also is useful in confirming the estimates of Sacandaga flow, the Hoosic being another of the important tributaries which enter above the main gaging station at Mechanicville. The record of the Hoosic flow is of special interest because this comes from a drainage area

whose rainfall is probably smaller than the average for the entire area above Mechanicville, probably averaging about 39 or 40 inches for the long term mean, and probably falling in extreme years as low as 28 or 29 inches, as shown by a study of the short-term records for Greenwich, Easton, Cambridge, Hoosic Falls, Eagle Mills, Lebanon Springs and a study of the isohyetal map.

The rainfall at Williamstown, Mass., a fairly representative locality for this drainage area, from 1852–1906, averaged 39.4 inches. The drainage area is in general rugged and steep, tending to rapid discharge.

The records of stream flow gagings may be found in reports of New York State Engineer for 1905, page 573, with hydrographs, complete records of daily discharge from the beginning to December 31, 1905, inclusive:

U. S. G. S. Water Supply Paper No. 202, page 23.
U. S. G. S. Water Supply Paper No. 166, page 25.
U. S. G. S Water Supply Paper No. 125, page 25.
U. S. G. S. Water Supply Paper No. 97, page 219.

The gaging station was established September 24, 1903. The height is read twice daily, and estimates of flow made from a rating curve established by occasional current meter measurements. In winter, flow is more or less retarded by ice, and although the height-gage may be read daily as usual for much of the time, the estimate rests largely upon assumptions about the degree of obstruction caused by the ice.

There are omissions in the published record for February 1906, which have been supplied by interpolation. From December 4, 1906, to March 15, 1907, the daily estimates have also been omitted because of ice.

It is understood that some careful studies of the flow when obstructed by ice have been made, corresponding to certain readings of height-gage, and it is expected that additional precise measurements of flow under the ice will be made during the present winter.

As a whole, these estimates of the daily and monthly discharge of the Hoosic river at Buskirk appear fairly reliable. The mass curve has therefore been computed and plotted for comparison with the diagrams of Plate 3.

IRREGULARITIES DUE TO SPIER'S FALLS POWER PLANT.

The development and use of the power station at Spier's Falls has introduced serious disturbances in the flow of the river from hour to hour, according to the varying demand for electrical power at different hours of the day.

Not only has this disturbed the operation of the paper mills at Glens Falls, and Fort Edward, but it has possibly interfered somewhat with the accuracy of the estimates of stream flow, because of the height over the dam being measured only twice in each twenty-four hours, and because of the more frequent changes caused in the operation of the turbines at times when no flow is passing over the dam.

The storage in the ponded river between Spier's Falls and the feeder dam tends to smooth out this irregularity, and the storage in the smaller

pond above the dams at Glens Falls and Sandy Hill tend to make the flow somewhat more regular at Fort Edward, and by the time Mechanicville is reached, this hourly irregularity has doubtless in large measure disappeared, so that error from this cause should not be serious at Mechanicville.

MASS CURVE COMPUTATIONS.

The best method known to the writer for computing the yield of a watershed from a continuous series of gagings and for at the same time determining the volume of reservoir storage required to store the flood waters for use in season of drought so as to maintain a specified constant rate of flow, is that known as the mass curve method.*

Briefly described, the method consists in adding up the totals of the daily or monthly yield from month to month for the whole period of gagings under consideration, then plotting the successive steps of accretion of the mass as an irregular line or "mass curve." Any desired rate of draft may then be assumed, and its successive sums plotted to the same scale, and if a uniform rate, this draft curve forms a straight inclined line, and if it is made to start co-incident with some point or summit on the "mass curve," the divergence of the two curves at successive points serves to show the volume of storage that would have been required on this date to have maintained the required rate of flow up to that time.

Since our river flow problems start with rainfall data given in inches depth over the entire watershed, this form of unit of measurement is commonly most convenient in studying the problems of reservoir depletion.

Mass curves for the Hudson river records at Mechanicville and Fort Edward and for the record of flow of its tributaries, the Schroon and the Hoosic, covering the whole period of observations, are presented in diagrams on plate No. 3.

A mass curve for the flow of the Croton is also shown during the period of smallest rainfall and greatest storage need that has occurred during the nineteen years covered by the Mechanicville gagings, because of the fact that the Croton records, maintained by the New York Department of Water Supply, present the most accurate and longest record of gagings of stream flow available within the State of New York and go back to a series of years of low rainfall more severe than has occurred since gagings on the Hudson were begun.

A study of the Hudson-Mechanicville mass curve makes it plain that on the Mechanicville basis, without addition for the relatively larger rainfall of the Sacandaga, with the great volume of storage proposed in the Sacandaga reservoir, which permits carrying over the surplus of years of large rainfall for use in years of small rainfall, a run-off of 1,700 cubic feet per second equivalent to 22 inches in depth from over the entire watershed, could have been maintained throughout every one of the twenty years since the beginning of the gagings at Mechanicville, and that the maximum depletion of storage caused at any time by this rate of draft would have amounted to 10.4 inches on the Sacandaga watershed of 1,050 square miles, equivalent to twenty-five billion cubic feet depletion of the proposed Sacandaga reser-

*NOTE.—This method is explained in detail in the report on New York's Water Supply made to Bird S. Coler, Comptroller, by John R. Freeman, 1900, page 227.

voir, corresponding to the volume contained between elevation 763 and elevation 737.*

ALLOWANCE FOR EVAPORATION FROM THE RESERVOIR SURFACE.

The best data on evaporation yet available are those determined from the experiments of Mr. Desmond Fitzgerald, made on the Boston water works and published in 1889; but owing to the greater altitude and greater coolness of the Adirondack region, it is probable that the loss from the water surface of the proposed Sacandaga reservoir would be somewhat less than found at the Chestnut Hill reservoir near Boston, where Mr. Fitzgerald's average results gave 39 inches annually for the mean value.

Mr. H. K. Barrows, Hydrographer, U. S. Geological Survey, has for three years past conducted experiments upon evaporation at several of the Maine lakes, and finds for the mean annual value, only 29 inches. Taking the mean of this and the Fitzgerald determination, we have 34 inches, and I believe this is about what may be expected from the Sacandaga reservoir, but in estimating the yield we have included the reservoir surface as a part of the drainage area, and therefore we do not have to deduct from the yield so large a quantity as the equivalent of 34 inches depth from the entire surface of the proposed Sacandaga reservoir.

The present problem is to determine the loss of water due to substituting a water area, varying from 42 to 26 square miles according to fullness of reservoir, for an equal land area from which there is at present a considerable loss by the evaporation of the rain that falls upon it, and which loss as found by deducting the run-off of 24 inches from the rainfall of 45 inches, averages 21 inches.

The total yearly loss by increased evaporation, due to flooding this land, therefore is 34 inches evaporation from a water surface minus 21 inches evaporation from a land surface, which gives 13 inches of increased loss over this area.

The area of water surface exposed to evaporation will lessen as the reservoir is lowered. It we call the average area of water surface 37 square miles, the loss of 13 inches depth over this area, due to substituting a water surface for a land surface is equivalent to about 36.0 cubic feet per second of constant flow daily throughout the year, which should be deducted from the yield as computed from the mass curves.

In the method of computation adopted above, we have included the area of the reservoir itself as a part of the drainage area and have made due allowance for this water surface being less efficient than the land surface as a gathering ground, because of its greater evaporation. Taking the mean

*NOTE.—The area of the Sacandaga watershed above its mouth at Hadley is given in the publications of the New York State Engineer and the United States Geological Survey as 1,040 square miles.

The topographic maps of the State, made in co-operation with the United States Geological Survey, were not all available at the time of these earlier estimated, and indeed one sheet (Stony Creek) is lacking at the present time.

From carefully tracing out the watershed line on all of these topographic maps and planimetering it and taking the Sacandaga area for the missing Stony Creek sheet from the best maps available, we find the area above Conklingville dam site is 1,050 square miles.

There is, however, some doubt as to where the dividing line should be drawn in the vicinity of Peck Lake, some five miles northerly from Gloversville, which according to the topographic maps has two outlets.

This should be investigated and the drainage area revised whenever the Stony Creek sheet of the topographic survey is available.

rainfall of this immediate locality as 45 inches and deducting for the probable evaporation from a water surface 34 inches, leaves 11 inches net gain in depth during the year upon the reservoir surface, exclusive of the stream flow into it.

The total loss by evaporation from the reservoir during the year taken at 34 inches in depth, is equivalent to a constant flow averaging for the year about 95 cubic feet per second, but during the months of July and August, in each of which a monthly loss of about 5.6 inches in depth of evaporation from a water surface may be expected, the equivalent constant uniform rate of loss in these months is about 156 cubic feet per second.

The recent experiments of the U. S. Reclamation Service made in Nevada, show the loss from a broad lake is proportionally less than from the ordinary experimental tank or than from a small reservoir.

The rate of flow from the entire Sacandaga watershed as measured near the end of the uncommonly severe drought of the past summer about September 1st, was 130 feet per second. We thus see that the evaporation loss from the lake surface may at times slightly exceed the inflow, so that the lake under these conditions of extreme drought would be lowered about one-thirtieth of an inch per day due to evaporation, although its outlet gates were shut tight, and its inflow was 130 second feet. In other words *there will seldom or never be a drought so severe that the inflow will not supply the evaporation loss.*

The net evaporation loss from the total watershed of 1,050 square miles, due to this water surface of nearly 40 square miles, is an extremely small portion of the total regulated flow, the 36 cubic feet per second of mean annual evaporation loss from the Scandaga reservoir as reckoned above being but 2 per cent. of the estimated yield of 1,700 cubic feet per second. We thus see that there need be no fear that the loss of water from so great a lake surface will be a serious feature in the problem.

DEPLETION DIAGRAM.

The table following and the diagram presented on plate No. 3, show the reservoir depletion that would have occurred with a constant twenty-four hour discharge for every day in the year at various rates from 1,700 cubic feet per second down to 1,475 cubic feet per second, the inflow to the reservoir being computed at the same rate per square mile as was actually measured at Mechanicville, and thus for the moment offsetting the 10 per cent. to 15 per cent. greater yield per square mile of the Sacandaga watershed to compensate for this evaporation and the possible margin of uncertainty in the Mechanicville gagings.

It is of interest to note from diagram No. 3 that in all the years since the gagings began, excepting the remarkably dry years of 1895 and 1901. the depletion called for by this very large constant discharge of 1,700 cubic feet per second, corresponding to 22 inches of annual run-off, would have amounted on the average to only about ten billion gallons, corresponding to lowering the reservoir only about 10 feet below its spillway level. It will also be seen from this diagram that in most years, water would have wasted over the spillway most of the time during the months of April and May.

This diagram of plate No. 4 is particularly interesting in showing how great the depletion of the reservoir below high water mark would have been from month to month throughout the past nineteen years, had constant quantities of 1,700 or 1,624 or 1,550 cubic feet per second, twenty-four hours per day been continuously drawn. It is, however, based on the Mechanicville gagings and therefore under estimates the Sacandaga yield.

The average rainfall per square mile of the Sacandaga drainage is shown by our isohyetal map of the Adirondack region on plate 10 to be probably 15 per cent. larger than that of the entire Hudson drainage area above Mechanicville, and therefore if precise accuracy of Mechanicville gagings be granted, it is probable that after allowing 2 per cent. for evaporation loss, 13 per cent. more water could be drawn with about the same depletion shown on this diagram, or say, about 1,900 cubic feet per second instead of 1,700.

HUDSON RIVER GAGINGS AT MECHANICVILLE.

STORAGE REQUIRED TO SUSTAIN VARIOUS CONSTANT RATES OF FLOW IN YEARS OF SMALLEST RAINFALL AND RUNOFF FOUND DURING THE ENTIRE PERIOD SINCE GAGINGS BEGAN.

RIVER OR STATION OBSERVED	FOR CONSTANT RATE OF DISCHARGE.		DRY PERIOD DURING WHICH NO WASTE WOULD OCCUR IF THIS RATE OF DRAFT WAS MAINTAINED.			Maximum storage required or reservoir depletion in inches caused by this draft.	Corresponding million cubic feet per square mile of total watershed.	Corresponding million cubic feet on Sacandaga of 1050 square miles.	MAXIMUM DEPLETION CAUSED IN OTHER YEARS BY THIS DRAFT.							
									2ND IN ORDER OF SEVERITY.		3D IN ORDER OF SEVERITY.		4TH IN ORDER OF SEVERITY.		5TH IN ORDER OF SEVERITY.	
	Runoff in inches per year.	Cu. ft. per second from 1050 sq. m.	Duration, Yrs. Mos.	From.	To.				Inches	Year.	Inches.	Year.	Inches.	Year.	Inches.	Year.
Mechanicville	24	1850	11 yrs.,11 mo.	June 1, 1893	May 5, 1906	18.4	42.7	44,700	8.0	1891	7.2	1889	5.9	1893	3.3	1890
Ft. Edward	24	1850	3 yrs.,10 mo.	June 1, 1899	Mar. 30, 1903	11.2	26.0	27,300	5.5	1905	5.2	1899	5.1	1897	3.2	1898
Schroon	24	1850	3 yrs.	June 1, 1898	May 25, 1901	11.3	26.2	27,500	11.6	1897	1.5	1898	.....	.....	.....	.....
Hoosic	24	1850	8 mo.	June 1, 1904	Mar. 10, 1905	4.6	10.7	11,200	3.8	1905	.....	.....	.....	.....	.....	.....
Croton	24	1850	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mechanicville	23	1775	5 yrs.,11 mo.	June 1, 1893	April 10, 1899	13.4	31.1	32,600	10.7	1901	7.5	1891	5.7	1889	5.2	1893
Ft. Edward	23	1775	3 yrs., 9 mo	June 1, 1899	Mar. 20, 1903	9.2	21.3	22,300	5.2	1905	4.6	1899	4.4	1897	2.7	1898
Schroon	23	1775	2 yrs.,	June 1, 1898	May 30, 1900	10.6	24.6	25,800	10.4	1897	7.8	1901	2.9	1897	1.4	1898
Hoosic	23	1775	8 mo.	July 1, 1904	Mar. 10, 1905	4.1	9.5	9,980	3.7	1905	.....	.....	.....	.....	.....	.....
Croton	23	1775	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mechanicville	22	1700	4 yrs.,10 mo.	June 1, 1893	Mar. 20, 1898	10.4	24.1	25,300	9.3	1901	7.2	1891	4.9	1888	4.8	1893
Ft. Edward	22	1700	2 yrs.	June 1, 1899	May 20, 1901	7.8	18.1	19,000	5.7	1902	4.4	1905	4.1	1899	3.6	1896
Schroon	22	1700	1 yr., 11 mo	June 1, 1898	April 25, 1900	9.8	22.8	23,900	9.7	1897	7.0	1901	2.8	1897	1.3	1898
Hoosic	22	1700	8 mo.	July 1, 1904	Mar. 5, 1905	3.8	8.8	9,240	3.2	1905	.....	.....	.....	.....	.....	.....
Croton	22	1700	7 yrs.,10 mo.	May 1, 1891	Mar. 10, 1899	16.0	37.1	39,000	3.2	1890	3.1	1888	1.4	1889	.....	.....
Mechanicville	21	1625	4 yrs.	June 1, 1893	June 10, 1897	8.0	18.6	19,500	7.8	1901	6.4	1891	5.7	1900	4.5	1888
Ft. Edward	21	1625	11 mo.	June 1, 1900	April 30, 1901	6.8	15.8	16,600	6.2	1899	5.0	1902	3.6	1905	3.5	1899
Schroon	21	1625	1 yr.	June 1, 1898	May 30, 1899	8.8	20.4	20,700	8.5	1897	6.2	1901	5.0	1899	2.6	1897
Hoosic	21	1625	8 mo.	July 1, 1904	Feb. 28, 1905	3.4	7.9	8,300	2.3	1905	.....	.....	.....	.....	.....	.....
Croton	21	1625	6 yrs.,10 mo.	May 1, 1891	Feb. 28, 1898	13.2	30.6	32,100	2.8	1890	2.7	1888	1.2	1889	.....	.....
Mechanicville	20	1550	1 yr.	June 1, 1900	May 20, 1901	7.0	16.3	17,100	6.2	1895	5.8	1891	5.1	1899	4.1	1893
Ft. Edward	20	1550	11 mo.	June 1, 1900	April 25, 1901	6.0	13.9	14,600	5.6	1899	4.3	1901	2.8	1905	2.7	1899
Schroon	20	1550	1 yr.	June 1, 1898	May 25, 1899	7.8	17.9	18,800	7.5	1897	5.5	1901	4.6	1899	2.4	1897
Hoosic	20	1550	7 mo.	July 1, 1904	Jan. 30, 1905	2.8	6.5	6,820	1.7	1905	.....	.....	.....	.....	.....	.....
Croton	20	1550	2 yrs.,11 mo.	May 1, 1891	Mar. 20, 1894	11.7	27.1	28,400	8.7	1896	6.4	1897	5.8	1894	2.6	1890

Mechanicville	19	1475	11 mo.	June 1, 1900	April 30, 1901	6.2	14.4	15,100	5.5	1895	5.2	1891	4.7	1899	3.6	1885
Ft. Edward	19	1475	11 mo.	June 1, 1899	April 25, 1900	5.2	12.1	12,700	5.1	1901	3.8	1902	2.3	1896	2.0	1905
Schroon	19	1475	11 mo.	June 1, 1898	May 15, 1899	7.1	16.5	17,300	6.7	1897	4.7	1901	4.2	1899	2.2	1897
Hoosic	19	1475	7 mo.	July 1, 1904	Jan. 20, 1905	2.3	5.3	5,560	1.2	1905	.....	.....	.....	.....	.....	.....
Croton	19	1475	2 yrs.	May 1, 1891	May 15, 1893	10.0	23.2	24,400	8.1	1896	5.6	1896	5.3	1894	4.4	1893

The starting points for the figures in this table are transcribed from the Mechanicville mass curve of plate No. 3.

The Sacandaga yield at Conklingville being probably 15 per cent. larger per square mile than that of the Hudson at Mechanicville, it is probable that the amounts of depletion shown in the above table would not be reached unless rate of draft of water was increased about 15 per cent. above that stated in the second and third columns of the above table.

CONFIRMATION BY OTHER GAGINGS.

According to the long series of daily gagings at Fort Edward, the computations show a draft of 23 inches, corresponding to 1,775 cubic feet per second on 1,050 square miles, could have been maintained from the Sacandaga reservoir throughout this period with a decidedly smaller depletion than called for by the Mechanicville gagings, and the gagings on the Schroon and the Hoosic tributaries as set forth in the preceding table call for still less storage to maintain 23 inches of run-off, notwithstanding the mean rainfall on Hoosic is about 10 inches less than on the Sacandaga, so that all four of these series of daily gagings made upon the upper Hudson and its tributaries, independently confirm the feasibility of regulating the discharge of the Sacandaga with twenty-five billion cubic feet of storage, so as to provide for a constant rate of flow of upward of 1,775 cubic feet per second. Taking account of differences of rainfall on the respective drainage areas, they conform the estimate of 1,900 cubic feet per second already stated on page 114.

COMPARISON WITH THE CROTON RECORDS OF RAINFALL AND RUN-OFF:

On making a comparison with the Croton records, the direct comparison is somewhat less favorable, until allowance is made for differences in rainfall, forest cover and evaporation. Assuming the run-off per square mile the same, it appears that for the years 1892 and 1895, which were dry years on the Croton, a discharge of 1,500 cubic feet per second could have been at all times furnished from a watershed of 1,050 square miles if storage of twenty-five billion cubic feet was available. In other words, the Croton record would indicate about 200 cubic feet per second less of constant draft would be obtained from an area equal to the Sacandaga drainage in the period from 1898 to 1907, than is given by the Mechanicville record for the same period.

As a warning against the smaller yield that may be expected in years of still smaller rainfall than any since 1888, or in what was probably the dryest year for more than half a century, the long term Croton records presented in the reports of the Croton Aqueduct Commission and discussed in detail in my report on New York's Water Supply made to the finance department in the year 1900, are of especial interest.

These records indicate that during the years from 1880–1882, which years gave the smallest run-off ever known, a flow of about 1,325 cubic feet per second could have been constantly maintained from a watershed of the same quality as the Croton having an area of 1,050 square miles and twenty-five billion cubic feet of storage available. This is about 200 cubic feet less than the Croton could have been maintained in the drought of 1895. The Sudbury records of the Boston water works concur wonderfully well with the Croton records in showing the same yield per square mile and the same storage requirement for the dry period of 1880–1882.

There can be no doubt that the yield per square mile of the forest-covered Sacandaga drainage is decidedly larger than for the Croton drainage area. The long term Croton rainfall average is 49.13 inches, for the 40 years 1868 to 1907 inclusive. The Sacandaga rainfall deduced from our preliminary

isohyetal map is forty-nine inches. The Sacandaga run-off will be much more in excess than the rainfall, because of the much larger proportion of forest and the higher altitude and the less evaporation.

The weir gagings of the New York Board of Water Supply on Esopus creek for the year 1907 show that the Catskill region gives a yield per square mile 10 per cent. larger than the Croton, although the rainfall at the Croton stations was 15 per cent. larger than for the Esopus stations. The real excess in runoff for this forest-covered mountain region was thus about 25 per cent. by this one year's observations.

The requirements for a water power are less exacting than those for domestic supply, so that independently of the Croton data for periods of drought and after allowing for a smaller evaporation loss, it seems safe to base our Sacandaga water power estimates upon a run-off on a yield decidedly larger than the Croton records of 1,325 cubic feet for the years of greatest drought in the past half century, or than the 1,500 cubic feet per second for the greatest Croton drought of the past twenty years, and to rely upon *at least* the 1,700 cubic feet per second already mentioned.

YIELD OF SACANDAGA DRAINAGE AREA COMPARED WITH YIELD OF HUDSON RIVER AT MECHANICVILLE.

Since it is the twenty years' record of daily gagings on the main Hudson river at Mechanicville, where the drainage area is 4,500 square miles, from which we have in the first instance determined the probable yield of the Sacandaga drainage of 1,050 square miles, it is important to know if the Sacandaga yields more or less per square mile than the remaining 78 per cent. of the Hudson river drainage above Mechanicville.

The most reliable method of determining this is by the comparison of certain series of stream gagings on the respective watersheds. I arranged for these at the earliest practicable date and am under much obligation to the hydrographers of the U. S. Geological Survey for the promptness with which they undertook this work, thereby obtaining a series of comparative measurements of the flow of several tributaries at the close of the remarkably severe drought of August, 1907, and prior to the beginning of the unusual heavy fall rains of this year.

The work of the hydrographic branch of the U. S. Geological Survey in its gagings of streams in New York, had been interrupted by failure of the last Congress to make the necessary appropriation, and as the survey had at its command experienced men admirably qualified for undertaking this work, an arrangement was made with the chief hydrographer by which certain gaging stations upon the upper Hudson and its tributaries were established, this work being paid for out of the funds appropriated by the Fuller bill, to the extent of reimbursing the Geological Survey for its actual expenditure in wages and traveling expenses of the men employed.

This arrangement has proved very satisfactory. The gagings have been under the personal supervision of Mr. H. K. Barrows, a hydrographer of much experience. The gage heights have been read daily and frequent current meter measurements have been made for establishing a rating curve at each station. The remarkably heavy rains of September, October and November gave uncommonly good opportunity for obtaining a wide range of rating

measurements. Looking backward, it is now easy to see that check measurements at Indian lake, heights in Schroon and other smaller storage lakes and check gagings at Mechanicville, would have been useful, and these should be taken during the coming year.

We made an earnest effort to obtain an elaborate series of rain-gage records to accompany these streams gagings, but owing largely to a failure to receive the necessary instruments on time, there was an unfortunate delay in beginning the record at the new stations.

The results of the gagings are shown in plate No. 3 and a brief abstract of the comparative results on the several subdivisions of the Hudson watershed is shown in the following table.

It will be noted that the flow of the Schroon is out of proportion to the flow of the other tributaries, by reason of the storage of three feet more or less in depth over the six and seven-tenths square miles area of Schroon lake, and as storage was being accummulated during this period from its watershed of 439 square miles above the Starbuckville dam, some disturbance is caused in its discharge record for these few months, which would disappear in the average of a year or more of daily observations.

The results plainly show that the Sacandaga responds to a rainfall more vigorously than the other tributaries, and that its yield per square mile is decidedly larger at all times, except near the end of an extreme drought.

The flow at Mechanicville at this time after the heavy rains was also thrown very slightly out of direct relation to the natural yield of the watershed, because of the flow from 131 square miles or nearly 3 per cent. of the drainage area above Mechanicville being withheld for the replenishing of storage in Indian lake. Until September fourth, the flow of the Hudson had been increased from time to time by water from Indian lake as is set forth on diagram in plate No. 5.

SUMMARY OF RIVER GAGINGS OF 1907.

Comparison of flow per square mile for various tributaries of the Hudson.

GAGING STATION.	Drainage area in square miles.	AS MEASURED JUST BEFORE END OF SEVERE DROUGHT.				RUN-OFF IN CUBIC FEET PER SECOND PER SQUARE MILE. MEAN FOR THE MONTH.			
		Date.	Cubic feet per second.	Per square mile.	As corrected for Indian Lake.	Sept.	Oct.	Nov.	Dec.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Sacandaga at Wells	263	Aug. 25	26	0.099	.....	.70	1.97	4.26	.....
Sacandaga at Northville	740	Aug. 24	76	0.103	.....	.69	2.70	4.70	4.22
Sacandaga at Hadley	1,050	Aug. 27	130	0.124	.....	.....	2.63	6.20	3.95
Schroon at Riverbank	535	Sep. 2	.95	0.18	.....	.34	1.02	2.86	2.12
Hudson at Gooley, above Indian River	428	Aug. 30	69	0.16	.....	.....	.....	.....	.....
(Below this point Storage released from Indian Lake modifies the flow)									
Hudson at North Creek	800	Aug. 29	779	0.97	0.16	.....	2.74	3.34	2.53
	.....	Aug. 31	770						
Hudson at Thurman	1,550	Aug. 28	1,150	0.74	0.32	.98	1.92	2.92	2.31
	.....	Aug. 31	832	0.54	0.3	.....	.....	.....	.....
	.....	Sept. 1	772	0.50	0.3	.....	.....	.....	.....
	.....	Sept. 2	844	0.54	0.3	.....	.....	.....	.....
Hudson at Fort Edward	2,800	.....	.....	.....	.....	1.26	2.61	3.66	3.23
Hudson at Mechanicville	4,500	Sept. 4	2,267	0.50	0.4	1.14	2.12	3.11	2.66

Daily flow of Schroon is affected by storage in Schroon Lake. Daily flow of Hudson is affected by storage in Schroon Lake and Indian Lake.

The flow of 775 second feet gaged at North creek on August twenty-ninth came mostly from Indian lake. Probably somewhere near 650 feet of the flow at North Creek, Thurman, Ft. Edward and Mechanicville at this time was coming from Indian lake, and in column six, a deduction, varying from day to day, has been made for this in order to obtain the natural flow.

One of the Indian lake sluice gates happens to have been shut on August 28th to September 1st inclusive. Both sluice gates were wide open at all other times, August 17th to September 4th. This somewhat disturbs the precision of this part of the comparison of gagings on Hudson.

NATURAL YIELD WITHOUT STORAGE IN TIME OF DROUGHT.

For the Sacandaga.

The three independent gagings at Wells, Northville and Hadley given in the preceding table concur in showing that the Sacandaga flow fell to the very low rate of 0.10 or 12 cubic feet per second per square mile in extreme drought, notwithstanding its excellent forest cover; the gagings for the four months following show that after the rains the Sacandaga run-off was increased in much larger degree than the Hudson run-off. A much longer period of comparisons than these three or four months is needed to establish this ratio with precision.

For the Upper Hudson.

The Hudson flow as recorded at Mechanicville near the end of the severe August drought held up unaccountably well in view of the small flow of its tributaries. This fact invites a study in detail during low water of next summer. Its flow including Indian lake averaged about 1,825 cubic feet per second, August 28th to 31st equivalent to 0.40 cubic feet per second per square mile, or deducting 600 cubic feet per second to correct for the storage drawn from Indian lake, gives a natural flow of 0.27 cubic feet per second per square mile. Assistant Engineer Shedd visited Mechanicville to review the record and seek explanation, but no reason is yet found for changing the Mechanicville record for 1907 from that given on page 105 and 120 in the discharge curves.

The regularity of the record at just the time of our drought gagings is somewhat disturbed by the fact that the paper mills at Mechanicville were shut down from August 20 to August 26th, and that on Sunday, September first, and Labor Day, Monday, September 2nd, the discharge was being held back in storage in the mill ponds.

The Spier's Falls records of flow through turbines is computed from the record of daily electric output, basing this computation on the turbine maker's statement of turbine discharge and efficiency ratio. For August 28th to 31st inclusive, the flow thus computed averaged 890 cubic feet per second, which is probably too small, since it takes no account of leakage, etc. This 890 cubic feet per second including Indian lake storage, is equivalent to 0.32 cubic feet per second per square mile, or deducting 600 feet for Indian lake leaves only 290 cubic feet per second, or about 0.11 cubic feet per second per square mile; also probably an underestimate. These figures are, however, not far from those quoted on page 66 from the census report of 1880, for low water flow, on the excellent authority of Mr. Warren Curtis.

So far as can be judged from these incomplete data, *the natural yield of the*

SCHROON RIVER AT RIVERBANK, NEW YORK.

Daily Discharge in Cubic Feet Per Second.

(Drainage Area 534 Square Miles.)

DAY.	Sept., 1907.	Oct., 1907.	Nov., 1907.	Dec., 1907.	Jan., 1908.
1	(95)	522	776	806	1,780
2	95	485	868	776	1,670
3	125	476	1,080	748	1,570
4	120	441	868	824	1,470
5	146	467	1,570	776	1,340
6	223	432	1,570	776	1,290
7	239	467	2,050	721	1,380
8	223	618	3,300	658	1,080
9	191	643	3,860	694	1,000
10	207	721	3,700	668	966
11	223	694	3,400	568	1,000
12	256	668	2,800	788	933
13	273	618	2,270	1,200	933
14	273	608	2,050	1,290	868
15	51	608	1,570	1,310	966
16	48	578	1,570	1,290	748
17	61	593	1,240	1,290	836
18	51	568	1,470	1,240	776
19	51	545	933	1,200	836
20	68	531	1,040	1,040	868
21	51	522	913	1,040	836
22	72	513	933	933	776
23	308	499	849	1,080	836
24	350	485	836	1,290	806
25	312	485	788	1,570	966
26	331	236	668	1,760	748
27	305	432	748	1,840	721
28	210	568	721	1,780	748
29	97	593	748	1,730	668
30	476	608	836	1,670	*a* 933
31	.....	668	.....	1,780	*a* 000
Mean	184	545	1,530	1,130	1,010

a Ice forming on shore.

Extreme low water flow corresponds to the 95 second feet equivalent to 0.18 cubic feet per second per square mile, measured on September second (just before the drought was broken by rainfall).

September 15–22, inclusive, is *not natural flow* as water was being held in Schroon lake by a dam completed at that time.

Discharge Measurements of Schroon River at Riverbank, New York, in 1907.

DATE.	Hydrographer.	Width.	Area of section.	Gage Height.	Discharge.
		Feet.	Sq. Ft.	Feet.	Sec. Ft.
Sept. 2	Barrows and Hoyt	42.5	102	1.18	94.8
Sept. 2	Barrows and Hoyt	41.5	100	1.18	91.2
Sept. 23	Hoyt and Pierson	63.0	177	1.90	321
Oct. 3	Pierson	67.0	190	2.26	463
Oct. 3	Pierson	67.0	185	2.25	438
Oct. 23	Pierson	65.0	190	2.32	492
Nov. 11	Pierson	84	419	5.47	3,360
Nov. 14	Pierson	71.0	298	4.33	2,000
Nov. 27	Pierson	67	214	2.92	768
Dec. 14	Pierson	74	266	3.63	1,240
Dec. 19*a*	Pierson	74	262	3.48	1,240

a Considerable anchor ice.

Rating Table for Schroon River near Riverbank, New York. From September 2, 1907, to December 31, 1907.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	Sec. Ft.	Feet.	Sec. Ft.	Feet.	Sec. Ft.	Feet.	Sec. Ft.
1.00.....	53	2.10.....	380	3.10.....	900	4.10.....	1,782
1.10.....	74	2.20.....	432	3.20.....	966	4.20.....	1,888
1.20.....	97	2.30.....	476	3.30.....	1,040	4.30.....	1,996
1.30.....	122	2.40.....	522	3.40.....	1,120	4.40.....	2,105
1.40.....	149	2.50.....	568	3.50.....	1,200	4.50.....	2,215
1.50.....	178	2.60.....	618	3.60.....	1,290	4.60.....	2,327
1.60.....	210	2.70.....	668	3.70.....	1,380	4.70.....	2,443
1.70.....	242	2.80.....	721	3.80	1,474	4.80.....	2,561
1.80.....	276	2.90.....	776	3.90.....	1,572	4.90.....	2,680
1.90.....	312	3.00.....	836	4.00.....	1,674	5.00.....	2,800
2.00.....	350	.....	.....	.....	.....	5.50.....	3,400
						6.00.....	4,000

The above table is applicable only for open channel conditions. It is based upon eleven discharge measurements made during 1907. It is well defined between gage heights 1.0 feet and 5.5 feet. The table has been extended beyond these limits. Above gage height 5.0 feet the rating curve is a tangent, the difference being 120 per tenth.

SACANDAGA RIVER AT WELLS, NEW YORK.

This station was established August 26, 1907, by H. K. Barrows, and is on the steel highway bridge over the east branch of the Sacandaga river in the southern part of the village of Wells, about 2½ miles above the junction of the east and west branches. The drainage area at this point is 263 square miles.

The channel is straight for about 25 feet above the station, then curving rather sharply to the left. It is straight for 100 feet or more down stream and then curves gently to the right. The right bank is about 12 feet high at ordinary stages and seldom or never overflows. The left bank is high and steep and never overflows. Both banks are skirted more or less continuously with bushes and small trees. The bed is rocky and quite rough, but permanent. There is one channel at all stages. The current is good at medium and high stages, but becomes sluggish and poorly distributed under low water conditions.

Discharge measurements are made from the upstream side of the bridge, the initial point for soundings being vertically over the top of the right abutment, upstream side. At low water, measurements are made by wading at a point about 800 feet upstream from the bridge, where a good gravel section is found.

An inclined staff gage which is read twice daily by Frank G. Stanyon, Jr., is fastened to bench marks as follows: (1) chisel draft on top of lowest stone of right abutment one foot from upstream side, elevation 5.38 feet; (2) chisel draft on bridge seat, right abutment, upstream side, elevation 21.06 feet. All elevations refer to gage datum.

SACANDAGA RIVER AT NORTHVILLE, NEW YORK.

Daily Discharge in Sec. Ft. of Sacandaga River at Northville, New York.

(Drainage Area, 740 square miles.)

DAY.	Aug., 1907.	Sept., 1907.	Oct., 1907.	Nov., 1907.	Dec., 1907.	Jan., 1908.
1	.....	74	1,380	2,340	862	.....
2	.....	74	862	1,980	880	.....
3	.....	92	640	*d*(7,000)	826	.....
4	.....	267	727	*d*(5,830)	790	.....
5	.....	500	1,920	4,580	*e*(790)	.....
6	.....	640	1,320	3,990	*e*(780)	.....
7	.....	465	1,060	18,900	*e*(770)	.....
8	.....	452	*a*1,980	14,300	*e*(760)	.....
9	.....	254	*b*(5,830)	6,650	*e*(750)	.....
10	.....	521	3,220	4,740	6,700	.....
11	.....	452	2,410	3,950	7,740	.....
12	.....	2,070	3.220	3,220	4,740	.....
13	.....	1,180	2,640	2,350	3,050	.....
14	.....	772	2,120	2,350	2,880	.....
15	.....	535	1,730	1,960	*e*(2,600)	.....
16	.....	465	1,380	1,560	*e*(2,400)	.....
17	.....	388	1,210	1,470	*e*(2,200)	.....
18	.....	290	1,080	1,360	*e*(1,900)	.....
19	.....	254	960	1,340	*e*(1,700)	.....
20	.....	237	880	1,250	*e*(1,400)	.....
21	.....	258	862	1,270	1,200	.....
22	.....	272	817	1,470	*e*(1,200)	.....
23	.....	237	727	2,090	*e*(2,000)	.....
24	76	330	687	1,370	11,500	.....
25	76	559	640	1,360	8,280	.....
26	76	521	599	1,290	4,140	.....
27	79	400	583	1,180	3,220	.....
28	79	340	*c*(7,000)	1,120	3,050	.....
29	79	420	*c*(5,830)	1,140	5,190	.....
30	73	1,960	4,540	960	4,980	.....
31	74	.....	3,050	.....	7,660	.....
Mean	.....	509	2,000	3,480	3,130	.....

a Gage height as observed at 9 a. m.—10 a. m. water over top of gage (i. e.) gage height 5.0, discharge approximated as corresponding to gage height 6.0.
b Water over top of gage—discharge approximated as corresponding to gage height 5.5.
c Water over top of gage—gage height Oct. 28 taken as 6.0; Oct. 29 as 5.5.
d Water over top of gage—gage height Nov. 3 taken as 6.0; Nov. 4 as 5.5.
e Anchor ice accumulations downstream caused backwater on gage,—discharge assumed

Discharge Measurements of Sacandaga River at Northville, New York, in 1907.

DATE.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	Sq. Ft.	Feet.	Sec. Ft.
Aug. 24	*a*Barrows and Hoyt	55	57.1	0.86	76.9
Aug. 24	*a*Barrows and Hoyt	55	57.5	0.86	76.0
Sept. 25	Pierson	260	956	2.03	603
Sept. 27	Pierson	260	930	1.92	466
Oct. 8	*b*Pierson	274	1,340	3.89	3,310
Oct. 18	Pierson	264	1,000	2.58	1,020
Oct. 22	Pierson	262	855	2.31	868
Nov. 7	*c*Pierson	284	2,570	9.68	18,300
Nov. 9	Pierson	277	1,420	5.81	6,310
Nov. 20	Pierson	264	953	2.78	1,360
Nov. 22	Pierson	266	958	2.98	1,410
Dec. 21	*d*Wood and Pierson	180	1,490	7.28	1,200

a Gaging made by wading, about ½ mile above staff gage.
b River rose 1.02 feet during gaging—results approximate only.
c Gaging by surface floats near Northville bridge.
d River frozen and gorged with anchor ice from a point about ½ mile upstream from gage to dam about 2 miles downstream. Gage height is to water surface but is not a true index of flow, gage height to top of ice=7.33, about; ice about 0.2 feet thick. Gaging made from highway bridge at Northville—considerable needle and anchor ice—results a pproximate only

Rating Table for Sacandaga River at Northville, New York. From August 24, 1907, to December 31, 1907.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	Sec. Ft.	Feet.	Sec. Ft.	Feet.	Sec. Ft.	Feet.	Sec. Ft.
1.00	95	2.70	1,180	4.40	3,610	6.10	7,260
1.10	115	2.80	1,290	4.50	3,800	6.20	7,520
1.20	140	2.90	1,400	4.60	3,990	6.30	7,790
1.30	170	3.00	1,510	4.70	4,180	6.40	8,060
1.40	205	3.10	1,630	4.80	4,380	6.50	8,340
1.50	245	3.20	1,750	4.90	4,580	6.60	8,620
1.60	290	3.30	1,880	5.00	4,780	6.70	8,910
1.70	340	3.40	2,010	5.10	4,980	6.80	9,210
1.80	400	3.50	2.150	5.20	5,190	6.90	9,520
1.90	465	3.60	2,290	5.30	5,400	7.00	9,840
2.00	535	3.70	2,440	5.40	5,610	7.10	10,170
2.10	615	3.80	2,590	5.50	5,830	7.20	10,510
2.20	700	3.90	2,750	5.60	6,050	7.30	10,850
2.30	790	4.00	2,910	5.70	6,280	7.40	11,190
2.40	880	4.10	3,080	5.80	6,510	7.50	11,530
2.50	980	4.20	3.250	5.90	6,750	8.00	13,230
2.60	1,080	4.30	3,430	6.00	7,000	9.00	16,630
						10.00	20,030

The preceding table is applicable only for open channel conditions. It is based upon eleven discharge measurements made during 1907. It is well defined between gage heights 0.8 feet and 3.0 feet and fairly well defined from 3.0 feet to 6.0 feet. The table has been extended beyond these limits. Above gage height 7.20 feet the rating curve is a tangent, the difference being 340 per tenth.

SACANDAGA RIVER NEAR HADLEY, NEW YORK.

This station was established September 13, 1907, by H. K. Barrows. It is located on the steel highway bridge about two and one-half miles west of Hadley (where the Sacandaga river enters the Hudson), between the towns of Corinth and Hadley. The drainage area at this point is 1,050 square miles.

The channel is straight for about 500 feet upstream from the bridge and for perhaps 100 feet downstream, where it curves gently to the left. The banks are high, rocky and permanent and do not overflow. The bed is rocky and very rough. The current is good at very low stages, and very strong at medium and high stages.

Discharge measurements are made by the use of a boat at a section about one mile downstream, where a good gravel section is found and smooth flow. At high stages measurements are made from the highway bridge at Hadley, just below the railroad bridge at that point. Measurements are not made at the bridge to which the gage is attached.

A standard chain gage which is read twice daily by W. W. Jeffers, is attached to the hand rail of the bridge in the left span near the center pier, downstream side. Length of chain 25.35 feet. The gage is referred to bench marks as follows: (1) circular chisel draft on highest point of boulder 3x5 feet, about fifty feet from down stream side of bridge near right abutment, elevation 6.50 feet; (2) chisel draft on downstream corner of right abutment at top, elevation 19.36 feet. All elevations refer to gage datum.

SACANDAGA RIVER AT HADLEY, NEW YORK.

Daily Discharge in sec. ft. of Sacandaga River at Hadley, New York.

(Drainage area, 1,050 square miles.)

DAY.	Sept., 1907.	Oct., 1907.	Nov., 1907.	Dec., 1907.	Jan., 1908.
1	.....	1,900	7,070	1,030	10,200
2	.....	1,520	5,950	970	9,270
3	.....	1,160	7,070	970	8,350
4	.....	1,030	11,200	915	5,630
5	.....	1,900	13,100	860	4,480
6	.....	2,130	10,700	810	3,000
7	.....	1,800	12,100	760	2,260
8	.....	1,900	12,600	810	1,800
9	.....	4,740	21,600	970	1,610
10	.....	5,020	19,200	1,290	1,520
11	.....	4,740	14,000	5,310	1,440
12	.....	4,230	11,600	13,100	1,360
13	1,610	3,770	9,740	11,600	1,520
14	1,360	2,540	6,670	7,910	1,700
15	915	2,020	5,310	4,740	1,520
16	715	1,800	4,740	3,560	1,360
17	630	1,610	3,360	2,840	1,290
18	520	1,360	2,130	2,540	1,220
19	490	1,090	1,700	2,130	1,160
20	460	1,030	1,610	1,900	1,090
21	430	1,030	1,360	1,800	1,030
22	400	915	1,440	1,700	970
23	430	915	1,520	2,260	915
24	490	860	1,610	3,770	860
25	590	810	1,520	5,630	860
26	715	760	1,360	7,070	760
27	670	760	1,290	8,350	670
28	630	1,900	1,220	6,670	810
29	670	9,270	1,160	7,070	970
30	1,360	10,700	1,090	8,810	*a* (1,000)
31	.....	10,200	.....	10,200	*a* (1,000)
Mean	.....	2,760	6,500	4,140	2,310

a River frozen over—anchor ice and back water—discharge assumed as 1,000.

SACANDAGA RIVER AT HADLEY, NEW YORK.

Discharge Measurements of Sacandaga River at Hadley, New York in 1907.

DATE.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	Sq. ft.	Feet.	Sec. ft.
Aug. 27...	Barrows and Hoyt	80.0	80.4	0.90	*a*130
Sept. 13...	Barrows and Hoyt	263	551	2.78	*b*2,150
Oct. 4...	Pierson	240	447	2.35	*b*1,690
Oct. 5...	Pierson	194	642	2.77	*c*1,810
Oct. 16...	Pierson	250	886	2.80	1,690
Oct. 17...	Pierson	250	892	2.80	1,690
Oct. 25...	Pierson	200	649	2.23	895
Oct. 25...	Pierson	200	649	2.23	914
Nov 19....	Pierson	250	942	2.88	*c*1,970
Dec. 16...	Pierson	120	898	3.50	*d*3,930

a Gaging by wading about 3,000 feet upstream from gage.
b Gagings made from bridge at gage—very rough—approximate only.
c Gagings Oct. 5 to Nov. 19 inclusive, made about one mile down stream from gage from a boat.
d Gaging made from highway bridge, just down stream from railroad bridge at Hadley.

Rating Table for Sacandaga River at Hadley, New York. From September 13, 1907, to December 31, 1907.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	Sec. ft.	Feet.	Sec. ft.	Feet.	Sec. ft.	Feet.	Sec. ft.
1.00.....	150	2.00	670	3.00	2,130	3.90	5.95
1.10.....	180	2.10	760	3.10	2,390	4.00	6.67
1.20.....	210	2.20	860	3.20	2,680	4.10	7.47
1.30.....	250	2.30	970	3.30	3,000	4.20	8.35
1.40.....	290	2.40	1,090	3.40	3,360	4.30	9.27
1.50.....	340	2.50	1,220	3.50	3,770	4.40	10.21
1.60.....	400	2.60	1,360	2.60	4,230	4.50	11.16
1.70.....	460	2.70	1,520	3.70	4,740	5.00	15.91
1.80.....	.. 520	2.80	1,700	3.80	5,310	5.50	20.66
1.90.....	.. 590	2.90	1,900	.....	.....	.....	.....

The above table is applicable only for open channel conditions. It is based upon ten discharge measurements made during 1907. It is fairly well defined between gage heights 1.0 feet and 3.0 feet and is only approximate above gate height 3.0. Above gage height 4.5 feet the rating curve is a tangent, the difference being 950 per tenth.

HUDSON RIVER AT NORTH CREEK, NEW YORK.

This station was established September 21, 1907, by W. G. Hoyt, at the steel highway bridge at North creek. The drainage area at this point is 804 square miles. North creek, a small tributary of the Hudson, enters from the right a short distance below this point.

The channel is straight for about 500 feet upstream and some 300 feet downstream curving to the left below here. The banks are high and rocky, clear up to the high water line and not liable to overflow. The bed is rocky

and of gravel and permanent but rather rough. There are two channels at all stages. The current is good at all stages, ranging from about one to five feet per second.

Discharge measurements are made from the upstream side of the bridge in the left span, and from the down stream side in the right span, the initial point for soundings being vertically over the left abutment, on the upstream side. A standard chain gage read twice each day by Gilbert Dean is attached to the floor of the bridge on the upstream side near the center of the right span; length of chain 22.11 feet. The gage is referred to bench marks as follows: (1) Chisel draft on 3 x 3 foot stone at foot of right abutment, upstream side, marked B. M. O, elevation 4.30 feet; (2) one inch square bolt on top of right abutment upstream side marked B. M. □, elevation 26.52 feet. All elevations refer to the datum of the gage.

HUDSON RIVER AT NORTH CREEK, NEW YORK.

Daily Discharge in sec. ft. of Hudson River at North Creek, N. Y.

(Drainage area, 804 square miles.)

DAY.	Aug., 1907.	Sept., 1907.	Oct., 1907.	Nov., 1907.	Dec., 1907.	Jan., 1908.
1	.....	.....	3,650	2,010	690	3,230
2	.....	.....	3,030	1,640	683	2,990
3	.....	.....	1,450	3,970	634	2,720
4	.....	.....	1,170	5,420	564	2,350
5	.....	.....	1,450	4,220	564	1,870
6	.....	.....	1,420	3,430	634	1,840
7	.....	.....	1,390	8,850	662	1,740
8	.....	.....	2,920	8,770	706	1,450
9	.....	.....	5,330	7,120	655	1,340
10	.....	.....	5,280	5,230	980	1,210
11	.....	.....	6,110	4,170	4,790	1,120
12	.....	.....	3,600	3,250	4,660	1,170
13	.....	.....	2,650	2,570	3,670	1,170
14	.....	.....	2,350	2,110	2,920	1,060
15	.....	.....	1,790	1,790	2,220	980
16	.....	.....	1,420	1,490	2,220	940
17	.....	.....	1,250	1,420	2,010	910
18	.....	.....	1,060	1,150	1,790	910
19	.....	.....	1,000	1,060	1,550	890
20	.....	627	930	1,030	1,390	860
21	.....	515	1,130	950	1,270	851
22	.....	634	1,080	950	1,290	842
23	.....	1,080	980	1,010	1,520	860
24	.....	1,120	806	1,010	3,140	860
25	.....	1,170	900	1,010	3,360	860
26	.....	1,100	1,120	980	3,210	860
27	.....	1,120	930	930	2,820	833
28	.....	1,060	1,960	900	2,570	770
29	779	1,190	3,530	860	2,990	770
30	.....	1,560	4,480	730	2,990	788
31	770	.....	1,770	.....	3,530	833
Mean	.....	.....	2,190	2,670	2,020	1,280

Discharge Measurements of Hudson River at North Creek, N. Y., in 1907.

DATE.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	Sq. ft.	Feet.	Sec. ft.
Aug. 29...	Barrows and Hoyt	235	547	2.91	788
Aug. 31...	W. G. Hoyt	235	502	2.90	716
Sept. 20...	W. G. Hoyt	237	506	2.71	618
Sept. 21...	Pierson and Hoyt	236	462	2.55	512
Oct. 1...	Pierson	250	834	4.09	2,380
Oct. 24...	Pierson	239	547	2.96	890
Nov. 12...	Pierson	250	937	4.52	3,290
Nov. 16...	Pierson	143	673	3.43	1,560

Rating Table for Hudson River at North Creek, N. Y.

From Aug. 29, 1907, to Dec. 31, 1907.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	Sec. ft.	Feet.	Sec. ft.	Feet.	Sec. ft.	Feet.	Sec. ft.
2.50	480	3.30	1,170	4.20	2,610	5.10	4,740
2.55	515	3.40	1,290	4.30	2,820	5.20	5,010
2.60	550	3.50	1,420	4.40	3,030	5.30	5,280
2.70	620	3.60	1,560	4.50	3,250	5.40	5,550
2.80	690	3.70	1,710	4.60	3,480	5.50	5,830
2.90	770	3.80	1,870	4.70	3,720	5.60	6,110
3.00	860	3.90	2,040	4.80	3,970	6.00	7,230
3.10	960	4.00	2,220	4.90	4,220	6.50	8,630
3.20	1,060	4.10	2,410	5.00	4,480	.....	.....

The above table is applicable only for open channel conditions. It is based upon eight discharge measurements made during 1907. It is fairly well defined between gage heights 2.50 feet and 4.50 feet. The table has been extended beyond these limits. Above gage height 5.4 feet the rating curve is a tangent, the difference being 280 per tenth.

HUDSON RIVER AT THURMAN, NEW YORK.

This station was established September 22, 1907, by W. G. Hoyt. Gage readings were obtained September 1–22 by a temporary staff gage set by H. K. Barrows on September 1. This station is located on the Delaware & Hudson R. R. bridge leading from Thurman to Warrensburg, about 950 feet below the highway bridge to Warrensburg, and some 2,000 feet below the entrance of Schroon River into the Hudson. The drainage area at this point is 1,550 square miles.

The channel is straight for about 1,000 feet above the station and some 400 feet down stream where the river divides into two channels forming an island of considerable size. The right bank is about eight feet high at ordinary stages, and is clear with the exception of a few trees along the river's edge. This bank overflows during high water, when flow occurs under another section of the bridge. The left bank is high and rocky, clear up to the high water line and does not overflow. The bed is of gravel and per-

manent. There are two channels under ordinary conditions, and three during high water as previously noted. The current is good at all stages.

Discharge measurements are made from the upstream side of the bridge on the line of the guard-rail, the initial point for soundings being vertically above the left abutment at the upstream side.

A standard chain gage which is read three times daily by S. H. Spencer is attached to the end of the ties outside the guard-rail about 100 feet from the left abutment; length of chain 29.08 feet. The gage is referred to bench marks as follows: (1) Nail in top of stump on left bank about sixty feet upstream from bridge, and forty feet from the water's edge. Elevation 12.94 feet; (2) top of 2½ inch iron pin on left abutment, upstream side, used for holding lateral brace, elevation 26.71 feet; (3) marked "R. P." on top of first floor beam from right abutment, one foot upstream from end of cross ties, elevation 26.83 feet. All elevations refer to the datum of the gage.

HUDSON RIVER AT THURMAN, NEW YORK.

Daily Discharge in Sec. Ft. of Hudson River at Thurman, New York.

(Drainage area, 1,550 square miles.)

DAY.	Sept., 1907.	Oct., 1907.	Nov., 1907.	Dec., 1907.	Jan., 1908.
1	772	3,480	3,260	1,900	.....
2	844	3,900	2,940	1,860	.....
3	1,010	2,250	4,210	1,840	.....
4	1,560	2,030	6,770	1,780	.....
5	2,870	2,110	6,050	1,760	.....
6	2,570	1,990	5,900	1,720	.....
7	1,940	2,030	11,200	1,700	.....
8	1,300	3,260	10,900	1,680	.....
8	1,280	5,760	9,860	1,680	.....
10	997	5,760	9,110	3,210	.....
11	796	7,400	7,400	5,880	.....
12	2,590	4,430	6,380	5,030	.....
13	3,360	3,930	5,670	4,350	.....
14	2,850	3,160	4,950	4,090	.....
15	2,110	2,700	4,180	3,740	.....
16	1,720	2,290	3,640	4,320	.....
17	1,220	2,090	3,330	3,740	.....
18	932	1,860	2,940	3,360	.....
19	808	1,660	2,590	3,110	.....
20	772	1,720	2,340	2,990	.....
21	590	1,840	2,400	2,800	.....
22	560	1,920	2,430	2,590	.....
23	1,040	1,600	2,400	2,750	.....
24	1,440	1,440	2,310	5,580	.....
25	1,420	1,400	2,270	5,640	.....
26	1,450	1,550	2,270	5,440	.....
27	1,320	1,660	2,200	5,150	.....
28	1,270	3,280	2,030	4,950	.....
29	1,660	5,270	2,010	5,090	.....
30	2,550	4,690	1,990	5,300	.....
31	.....	3,960	.....	6,020	.....
Mean	1,520	2,980	4,530	3,580	.....

Discharge Measurements of Hudson River at Thurman, New York, in 1907.

DATE.	Hydrographer.	Width.	Area of section.	Gage height.	Discharge.
		Feet.	Sq. ft.	Feet.	Sec. ft.
Aug. 28...	Barrows and Hoyt	260	757	2.86	1,150
Aug. 31...	Barrows and Hoyt	251	683	2.49	832
Sept. 1...	Barrows and Hoyt	253	662	2.46	777
Sept. 22...	W. G. Hoyt	230	550	2.05	476
Sept. 30...	Pierson	275	962	3.48	2,640
Sept. 30...	Pierson	275	960	3.47	2,700
Oct. 15...	Pierson	277	963	3.52	2,800
Oct. 26...	Pierson	260	769	2.75	1,400
Nov. 4...	Pierson	299	1,460	4.98	6,760
Nov. 13...	Pierson	301	1,280	4.54	5,790
Nov. 18...	Pierson	280	991	3.58	2,970
Dec. 12...	Pierson	292	1,270	4.60	6,340

Rating Table for Hudson River at Thurman, New York. From August 28, 1907, *to December* 31, 1907.

GAGE HEIGHT.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	Sec. ft.	Feet.	Sec. ft.	Feet.	Sec. ft.
2.20	550	3.20	2,070	4.20	4,570
2.30	650	3.30	2,290	4.30	4,860
2.40	760	3.40	2,520	4.40	5,150
2.50	880	3.50	2,750	4.50	5,440
2.60	1,010	3.60	2,990	4.60	5,730
2.70	1,150	3.70	3,230	4.70	6,020
2.80	1,300	3.80	3,480	4.80	6,320
2.90	1,470	3.90	3,740	4.90	6,620
3.00	1,660	4.00	4,010	5.00	6,920
3.10	1,860	4.10	4,290	.....	.....

The above table is applicable only for open channel conditions. It is based upon eleven discharge measurements made during 1907. It is fairly well defined between gage heights 2.5 feet and 5.0 feet. The table has been extended beyond these limits. Above gage height 5.0 feet the rating curve is a tangent, the difference being 300 per tenth.

DISCHARGE MEASUREMENTS IN JANUARY, 1908.

DATE.	Hydrographer.	Width	Area of section.	Gage height.	Discharge.	Remarks.
			Hudson River at North Creek, N. Y.			
		Feet.	Sq. ft.	Feet.	Sec. ft.	
Jan. 22..	Wood and Pierson.....	240	523	3.00	746	Some anchor ice.
			Sacandaga River near Hadley, N. Y.			
Jan. 4..	J. B. Pierson.....	120	16	3.80	4,510	Anchor ice.
Jan. 24..	Wood and Pierson.....	115	617	2.37	1,150	Anchor ice.
			Sacandaga River at Northville, N. Y.			
Jan. 1..	J. B. Pierson.....	273	1,300	4.54	3,350	
			Sacandaga River at Wells, N. Y.			
Jan. 27..	D. M. Wood.....	67.5	168	4.83	269	Anchor ice.
			Schroon River at Riverbank, N. Y.			
Jan. 23..	Wood and Pierson.....	72	216	3.02	751	Anchor ice.
			Miscellaneous Measurements.			
			North Creek at North Creek, N. Y.			
Jan. 22..	Wood and Pierson.....	30	26.0	.....	27.0	By wading meter on rod.

CONFIRMATION OF ESTIMATES OF HUDSON FLOW BY RAINFALL STUDIES.

Frequently in problems of power development, the only reliable basis for estimating the amount of power that can be developed, is furnished by a measurement of the watershed area, a study of the rainfall and a comparison with rainfall records on similar watersheds from which run-off has actually been measured, and although in the present case, the gagings at Mechanicville, gave a much better basis for estimating the yield of the Sacandaga and other tributaries, it was deemed prudent to confirm these estimates based on gagings by studies of the rainfall and by comparisons with the yield of other watersheds.

The first question to be answered by a study of the rainfall records is whether the average yield of the 1,050 square miles of Sacandaga drainage is substantially the same as that found for the 4,500 square miles above Mechanicville. The chief results of our enquiry on this point have already been stated, but some further notes are of interest.

The rainfall records upon the elevated Adirondack plateau are few and far between as compared with other portions of the State. The most complete compilation is found in the study by Mr. Emil Kuichling, published in the Barge Canal Report and summed up in his isohyetal map, on plate 27 and described in page 795 of the Barge Canal Report of 1901.

The records for most of the stations there quoted have been obtained for the later years, and in order that discrimination might be made in the use of these records and greater weight given to those where the surroundings for the rain-gage were more favorable or where it appeared that the observer was more painstaking, I arranged for Prof. Francis J. Seery of Cornell University to make a personal inspection of all the rain-gages in the Adirondack plateau, with an examination of the original records and conference with the observers.

REPORT BY PROF. FRANCIS J. SEERY UPON THE SEVERAL RAIN-GAGE STATIONS IN THE ADIRONDACK PLATEAU.

The surroundings of each of the several gages found in use at the beginning of our work are shown in the following sketches. Prof. Seery found little data from which to judge of the accuracy of observation at many of the stations and we have yet found little to justify giving greater weight to the record of one station than to that from another, save in the length of period covered and in noting how it conforms to record of two or more neighboring gages, or in conforming to the probable course of the isohyetal curve. Brief notes regarding quality of observations at some of the stations are given in the following sketches.

ADDITIONAL RAIN-GAGE STATIONS IN ADIRONDACKS.

The following named new stations were established in order to close gaps in the existing lines of stations. The locations are shown on the isohyetal map of the Adirondack region, plate 10.

There was a failure from one cause and another to get the new gages set in time to obtain comparisons of the precipitations in the very remarkable rainstorms of September and October. It is proposed to continue observations at these stations indefinitely. Maximum and minimum thermometers of the Weather Bureau pattern were supplied at each rain-gage station and are exposed in standard thermometer shelters and the readings taken daily.

The records at Nehasane obtained to January 31st are given in following table.

RAIN OR SNOW, AND TEMPERATURE, AT NEHASANE, HAMILTON COUNTY, N. Y.

L. W. Brown, Observer.

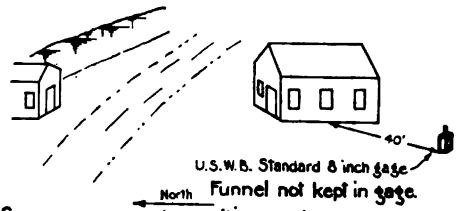
	NOVEMBER, 1907.				DECEMBER, 1907.				JANUARY, 1908.			
	DURING 24 HOURS PRECEDING 6 P. M.		TEMPERATURE, DEGREES FAHR.		DURING 24 HOURS PRECEDING 6 P. M.		TEMPERATURE, DEGREES FAHR.		DURING 24 HOURS PRECEDING 6 P. M.		TEMPERATURE, DEGREES FAHR.	
	Inches rain or melted snow.	Measured depth of snow.	Minimum.	Maximum.	Inches rain or melted snow.	Measured depth of snow.	Minimum.	Maximum.	Inches rain or melted snow.	Measured depth of snow.	Minimum.	Maximum.
1	0.00	0.0	24	55	.03	.6	6	28	.50	9.5	21	26
2	.11	0.0	30	48	.04	.7	16	24	.03	1.	12	24
3	1.01	0.0	34	54	T	T	9	21	.05	.8	3	22
4	.14	.5	25	37	0.00	0.00	—11	19	.25	3.3	—7	31
5	T	T	24	44	0.00	0.00	—16	20	.25	4.	—6	31
6	.16	0.0	32	45	.01	.2	12	29	0.00	0.0	—19	20
7	1.24	2.5	30	43.5	T	0.0	21	33	.14	1.	—5	20
8	.36	2	27.5	36	T	0.0	22	38	.60	6.	22	29
9	T	T	28	43.5	.07	0.0	22	48	.05	1.20	6	26
10	0.00	0.0	28	43.5	.91	0.0	30	48	.02	2.	—11	13
11	.06	0.0	26	37	.46	3.	20	40	0.00	0.0	—3	34
12	.07	.5	19	34	.08	3.3	7	21	.27	.5	18	35
13	0.00	0.0	18	28.5	0.00	0.0	—9	21	.09	.2	20	34
14	.54	11	14	30	.17	2.5	8	23	.03	.7	1	21
15	T	T	13	21	.42	4.	19	32	.02	.4	—12	27
16	T	T	3	30	.13	1.5	24	30	.26	4.2	4	30
17	0.00	0.0	11	35	.06	1.5	19	25	.02	1.	—10	21
18	0.00	0.0	12	36	.12	3 5	18	24	.05	1.5	11	24
19	0.00	0.0	14	40	.20	4 6	13	24	.25	4.	7	26
20	0.00	0.0	21	37	T	T	17	24	0.00	0.0	—11	34
21	.16	0.0	22	40	.09	1.2	12	29	T	T	6	44
22	.03	0.0	35	44	0.00	0.0	16	27	.52	2.	24	39
23	T	0.0	32	44	1.20	10.0	21	37	.01	.2	2	24
24	0.00	0.0	18	37	.23	.8	26	40	.01	.2	7	20
25	.17	1.2	20	33	.20	1.5	9	29	.07	2.7	—18	19

RAIN OR SNOW, AND TEMPERATURE, AT NEHASANE, HAMILTON COUNTY, N. Y.— (*Continued.*)

L. W. Brown, Observer.

	NOVEMBER, 1907.				DECEMBER, 1907.				JANUARY, 1908.			
	DURING 24 HOURS PRECEDING 6 P. M.		TEMPERATURE, DEGREES FAHR.		DURING 24 HOURS PRECEDING 6 P. M.		TEMPERATURE, DEGREES FAHR.		DURING 24 HOURS PRECEDING 6 P. M.		TEMPERATURE, DEGREES FAHR.	
	Inches rain or melted snow.	Measured depth of snow.	Minimum.	Maximum.	Inches rain or melted snow.	Measured depth of snow.	Minimum.	Maximum.	Inches rain or melted snow.	Measured depth of snow.	Minimum.	Maximum.
26	.18	2	16	31	.17	1.5	18	32	.....	.....	.....	.....
27	.11	.8	17	33	0.00	0.0	9	45	.....	.....	.....	.....
28	.16	2.5	23	28	.50	0.0	33	45	.....	.....	.....	.....
29	.28	2.7	15	34	0.00	0.0	13	34	.....	.....	.....	.....
30	0.00	0.0	6	25	.53	0.0	21	41	.....	.....	.....	.....
31	.....	.....	.....	.....	.13	2.6	9	39	.....	.....	.....	.....
	4.78	25.7	.....	.....	5.75	43.0	.....	.....	.....	.....	.....	.....

Steep hillside makes location rather poor.



Funnel not kept in gage.

Snow measured by melting contents of can also measuring depth in several places.

SPIERS FALLS

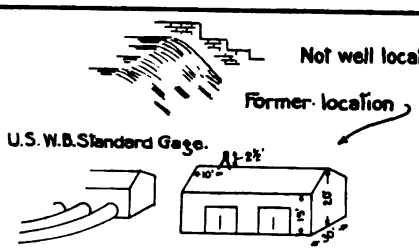
Station since fall of 1906. On sloping hillside covered with low brush and weeds.

About ¼ mile from former location. Hill Slopes about 25%

Established 1902

Not well located

Former location



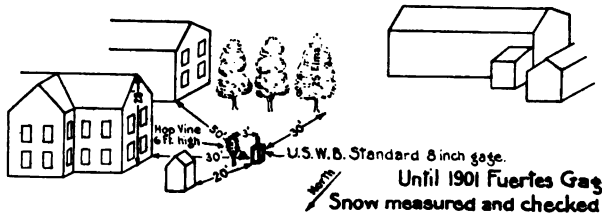
SPIERS FALLS

Station from 1902 to fall of 1906 on roof of barn which stands on edge of steep slope to river. Nothing higher than gage save the hills. A site greatly affected by wind eddies.

Established Oct. 1891

Prop. C.L. Williams Observer.
Located many years at Academy
60 feet from buildings 2 feet above ground.

"Careful, Faithful, Excellent"



GLENS FALLS

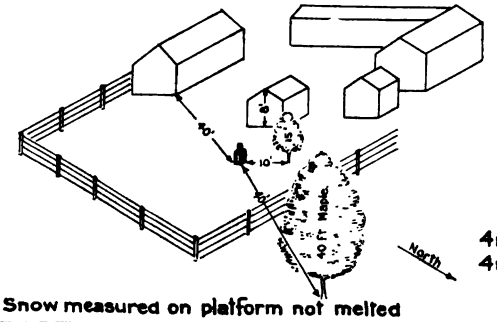
Station at residence of Prof. C.L. Williams on Ridge St.

Present Location

Until 1901 Fuertes Gage used.

Snow measured and checked by measurement.

Established 1897



Possibly less valuable than some other records of the

GREENFIELD
Saratoga County.

Station in henyard of Mr. S.E. Darrow on Saratoga-Corinth Road on Westcott Hills.

4 miles N.W. of Saratoga
4 miles S.E. of Kings

Snow measured on platform not melted

Drawn by Raymond E. Cranston from notes by F.J. Seerey.

PLATE 6

Schroon Lake, Essex county, established September, 1907, by F. J. Seery. observer Dr. F. S. Cole. Site in a garden in rear of house on Main street about 100 yards south of post-office and about one-eighth mile from lake and twenty-five feet above. The site is free from obstructions near the gage.

An arrangement for the supervision and compilation of the records from the new stations established was finally made with the Section Director of the United States Weather Bureau, Mr. Wilfred Wilson, Ithaca, New York.

RAINFALL COMPILATIONS. CYCLES OF WET AND DRY YEARS.

It is well known that the yield of a watershed for purposes of domestic supply, or for water power. is most severely tested only at long intervals, and that cycles of years of large rainfall alternate with successive years of smaller rainfall. The most severe test within the historic period is found in the Croton in the series of years from 1879 to 1892, and the same period also gave the most severe shortage of water upon the Sudbury river supplying Boston. It is well known that for some years past, the rainfall has averaged above the normal, or larger than shown by an average of the records of the last three-quarters of a century.

A study was therefore made of all available long term records within the vicinity of the upper Hudson, in order to learn if the period covered by the nineteen years of gagings of the Hudson flow at Mechanicville, which has served as our main reliance in deducing the average flow and the storage requirement for the upper Hudson, afforded a more generous supply than could be relied on throughout a long period.

A comparison of all records of annual rainfall for the Adirondack region is presented in plates 1 and 2. In plate 1 the record is given in terms of total precipitation, and in plate 2 the record for each year is plotted in terms of ratio to the long term mean or normal.

In examining these diagrams, it will be noted that while observations at the different stations agree in a general way in showing which were the dry years and which were the wet years, and ordinarily show some approximate agreement in the ratio of the rainfall in any given year to the long term mean, there are numerous instances when there is no agreement. In general, the exceptions and lack of concurrence found in the records of the Adirondack region are much more erratic than in the case of the Genesee records and sundry other regions for which I have made similar comparisons. The proximity of mountains and the great lakes and the position of the elevated station in relation to vapor laden winds from the ocean, might naturally lead one to expect occasional disturbances or lack or regularity or concurrence between stations in the vicinity of the Adirondack plateau.

In general, from a study of this diagram, we find no reason to regard as abnormal to any noteworthy degree the precipitation upon the drainage areas of the upper Hudson during the period covered by the gagings at Mechanicville, on which we base our estimates of flow.

The records compiled for this purpose were also utilized in a new study of the isohyetal lines, shown in plate 10 made for dertermining the rela-

ion of the rainfall on the Sacandaga drainage to that on the entire drainage bove Mechanicville.

There were many short term records also available for parts of the territory ot otherwise covered, and in order to compensate for abnormal rainfall of certain years and reduce all of these observations to the same basis before drawing the isohyetals, the method was adopted of correcting the average of each short term series of records to make it conform to the normal or long term average by first finding at the neighboring long term stations what percentage the rainfall in each of the years covered by the said short record had borne to the long term average and then compensating the average of the short term series in the same ratio. The following tables will make the method clear.

RECORDS OF RAINFALL AT STATIONS IN OR NEAR THE DRAINAGE AREA OF THE HUDSON RIVER, ABOVE MECHANICVILLE. COMPENSATED FOR SHORT TERM VARIATIONS.

RAINFALL STATION.	Elevation.	Annual mean inches.	Years.	Duration of record.	Probable ratio of rainfall in this period to the long term mean.	Compensated annual mean for this station.
	Feet.			Dates from—to—inclusive.	Per cent.	Inches.
Albany	97	38.72	81	1826-1906	100	38.7
Axton	1,600	40.23	1	1900	102	39.6
Blue Mt. Lake	1,771	48.94	6	1900-1905	106	46.1
Burlington	346	32.81	8	1886-'89; '91; 1895-'97	98	33.5
Cambridge	500	40.11	13	1827-1839	102	39.3
Canton	304	40.69	7	1889-'92; 1895-'96; 1898	123	33.1
Constableville	1,246	61.08	2	1890-'91	99	62.0
DeKalb Junction	440	37.14	8	1891-'92; 1894-'98; 1905	111	33.4
Easton	440	39.26	5	1891-'92; 1903-'04; 1906	100	39.3
Gabriels	1,800	34.00	3	1901; 1904; 1906	99	34.4
Glens Falls	340	37.66	23	1879-'80; 1892-'91; 1895-'97	100	37.7
Gloversville	850	44.41	14	1893-1906	86	51.6
Gouverneur	423	30.44	26	1833-'35; 1838-'39; 1841-'45; '47-'48; '55-'74	100	30.4
Greenwich	425	37.17	8	1898-'99; 1901-'06	100	37.2
Houseville	900	48.22	3	1867-1869	108	44.7
Indian Lake	.....	40.71	7	1900-1906	104	39.1
Johnstown	688	39.97	17	1828-'45; 1881; -'83	100	40.0
Keene Valley	1,000	35.99	23	1879; '94; '98; 1900-'04; '06	100	36.0
Kings Station	588	46.83	9	1892-1900	108	43.4
Lake George	350	43.03	9	1897, 1899-'06	100	43.0
Little Falls	1,526	47.26	7	1897-'01; 1904; 1906	89	53.0
Lowville	900	36.24	37	1827-'48; '51-'52; '57-'58; '60; '91-'05	100	36.2
Malone	810	37.88	8	1839-'42; 1891-'95	91	41.6
North Lake	1,822	54.25	3	1897-1899	98	55.7
Number Four	1,571	50.00	11	1890-1900	104	48.1
Plattsburg Barracks	125	34.60	18	1843-'45; 1847-'59; 1890-'95; 1897	100	34.6
Potsdam	394	31.81	28	1828-'48; 1889-'91; 1893; '95-'97; 1905	100	31.8
Salem	490	32.03	6	1840-41; '43-46	108	29.6

Saranac Lake	1,750	35.79	12	1889; '94–'96; '98–'99; 1901–'05	100	35.8
Saratoga	316	40.31	5	1900–'02; '04–'05	93	43.3
South Hartford	500	40.02	10	1864–'67; 1870–'72; '76–'78	106	37.7
Stillwater	100	33.49	1	1894	89	37.6
Ticonderoga	128	33.20	7	1898; 1900–'05	100	33.2
Turin	1,200	52.92	6	1890–'95	105	50.4
West Day	1,200	44.76	1	1872	100	44.8
Williamstown	760	39.24	31	1855; '58; '60–'61; '64; '66–'68; '70–'71; '76; '80; '85; '88; '92–'93; '95–'07	100	39.2

COMPARISON OF RAIN GAGES.

Studies of long term rainfall records in the vicinity of New York city and upon Long Island* have made it plain that in some cases the smaller precipitation recorded in early years was due to the use of less perfect types of rain gages than those used commonly during the past ten or twenty years. A series of experiments has therefore been begun at my request, in which duplicates of the type of gages used in the earliest observations have been constructed and exposed side by side with modern gages. One set of these experiments is being carried on at the weather bureau station at Cornell University, Ithaca, N. Y., and another set at the Clarkson Memorial Institute at Potsdam, N. Y.

There was an unfortunate delay in the completion of these gages prior to the remarkably heavy rainfalls of last September and October, and thus the number of comparisons in individual storms obtained up to the present time is not sufficient to be at all conclusive. The observations are being continued and forms a part of the work provided for under the specifications and appropriation of the Fuller bill.

LARGER RUN-OFF OF THE SACANDAGA DRAINAGE AREA.

Even after the most careful review of all existing records, the rainfall upon the several portions of Adirondack watershed remains at present not well determined, and awaits longer records and the few years records from additional stations recently established.

Meanwhile, I have had to draw the isoheytals of plate 10 with somewhat of a bold sweep from the compensated records of the several rainfall stations after a study of the elevations shown on the topographic maps and a consideration of the lay of the land in relation to the probable general course of the vapor-laden winds for the same period. Since preparing this isohyetal map, my attention has been called to a similar map in the U. S. Monthly Weather Review for January, 1907, by Mr. R. E. Horton, in which I am pleased to find very much the same conclusions are independently reached.

These rainfall records and isohyetal maps make it plain beyond a doubt that the Sacandaga rainfall averages about five or six inches larger than for the Hudson above Mechanicville as a whole, and it is also certain because of greater average altitude and the probable larger per cent. of forest cover that the evaporation loss is less. Therefore, the Sacandaga run-off must be decidedly larger than that at Mechanicville.

I am led to believe from the data shown on our preliminary isohyetal map, that the average annual precipitation on the Sacandaga drainage is at least forty-nine inches, being less than 45 inches at the easterly end and more than fifty-five inches at the westerly end, and that the average rainfall is probably somewhat in excess of the mean values shown by the stations heretofore observed, because of the greater precipitation on the hills and mountains than in the valleys where the older rain gages are located.

The mean annual rain fall for the entire Hudson basin above Mechanicville is probably about 43 inches. If so, the precipitation on the 1,050 square miles of Sacandaga drainage is six inches larger than for the entire area of

* See Burr-Hering-Freeman Report on Additional Water Supply for New York City 1900 p. 683 et seq.

4,500 square miles above Mechanicville. Since the run-off in this forest covered mountainous region is fully half the rain fall, this six inches of extra rain fall would add at least three inches to the run-off. There is no reason for thinking that the ratio of run-off to rain fall would be less, indeed the contrary is true and so we may expect 15 per cent more run-off per square mile on the Sacandaga than on the Hudson, and since our mass curves have shown that a draft equivalent to twenty-two inches run-off may be relied upon from the Mechanicville records for the entire upper Hudson, we are justified in expecting 22+15 per cent.= 25.3 inches run-off from the Sacandaga, or about 1,950 cubic feet per second, instead of the 1,700 derived from the Mechanicville curve.

The Esopus experience quoted on page 118 in comparison with the Croton, indicates a much larger rain fall and run-off from the mountains than from the lowlands, and long term records are more likely to increase than to diminish this figure of 1,950 cubic feet per second of flow constantly available from the Sacandaga reservoir as proposed.

YIELD OF WATER POWER FROM THE ESTIMATED FLOW FROM SACANDAGA RESERVOIR.

Estimating the Sacandaga reservoir yield conservatively at 1,700 cubic feet per second to allow for lack of precision in gagings and for more severe droughts and calling the extreme average net available fall 185 feet and the turbine efficiency 75 per cent. we obtain:

$$\frac{1{,}700 \times 62.4 \times 185 \times 75\%}{550} = 26{,}761 \left\{ \begin{array}{l} \text{mechanical horse power on turbine} \\ \text{shafts 24 hours per day, 7 days in} \\ \text{the week, throughout the dryest year.} \end{array} \right.$$

or, say,.....25,000 horse power.

Should we thus take all elements at the maximum, the flow at 1,900, the working fall at 185 and the turbine efficiency at 80 per cent. the 24-hour 7 day average of power from the Sacandaga becomes about 30,000 net horse power on the turbine shaft instead of the 25,000 as previously figured, and this 30,000 horse power 24 hours 7 days in the week is the most probable figure for the complete Sacandaga development, and under use with a 40 per cent. load factor would generate at 95 per cent. efficiency 53,200 kilowatts, which at 85 per cent. efficiency in transformation and transmission would deliver in ordinary working hours a maximum of 60,500 horse power to the consumer, exclusive of the power added by this stored water at the sites all along the Hudson from Palmers Falls to Troy. This gives the measure of the new power plant to be planned.

INCREASE OF POWER AT THE PRESENT HUDSON RIVER PLANTS DUE TO THE DISCHARGE OF STORAGE FROM THE SACANDAGA RESERVOIR.

As has been already stated, this reservoir may be used according to two different methods for the benefit of the power sites upon the Hudson river. In the early years or before the long tunnel and power plant near Hadley are built, the storage can be all used for reinforcing the flow of the Hudson, holding it all back in those months when water in the main river is plenty

and changing the rate of discharge from the Sacandaga from day to day, so as to maintain the Hudson flow at a uniform rate at some mean location such as Spier's Falls, or perhaps at Mechanicville if navigation interests are paramount.

While I believe the greatest good would be found by selecting some locality farther upstream than Mechanicville as the point of control, thus regarding the water power as the paramount interest, I have based the following computation upon maintaining the flow constant at Mechanicville, as was done in the earlier reports of the State Engineer.

The first step in this computation is the determination of the average flow in the Hudson month by month, and much better results are obtained by first arranging the months for taking the average in their order of dryness instead of in their calendar order.

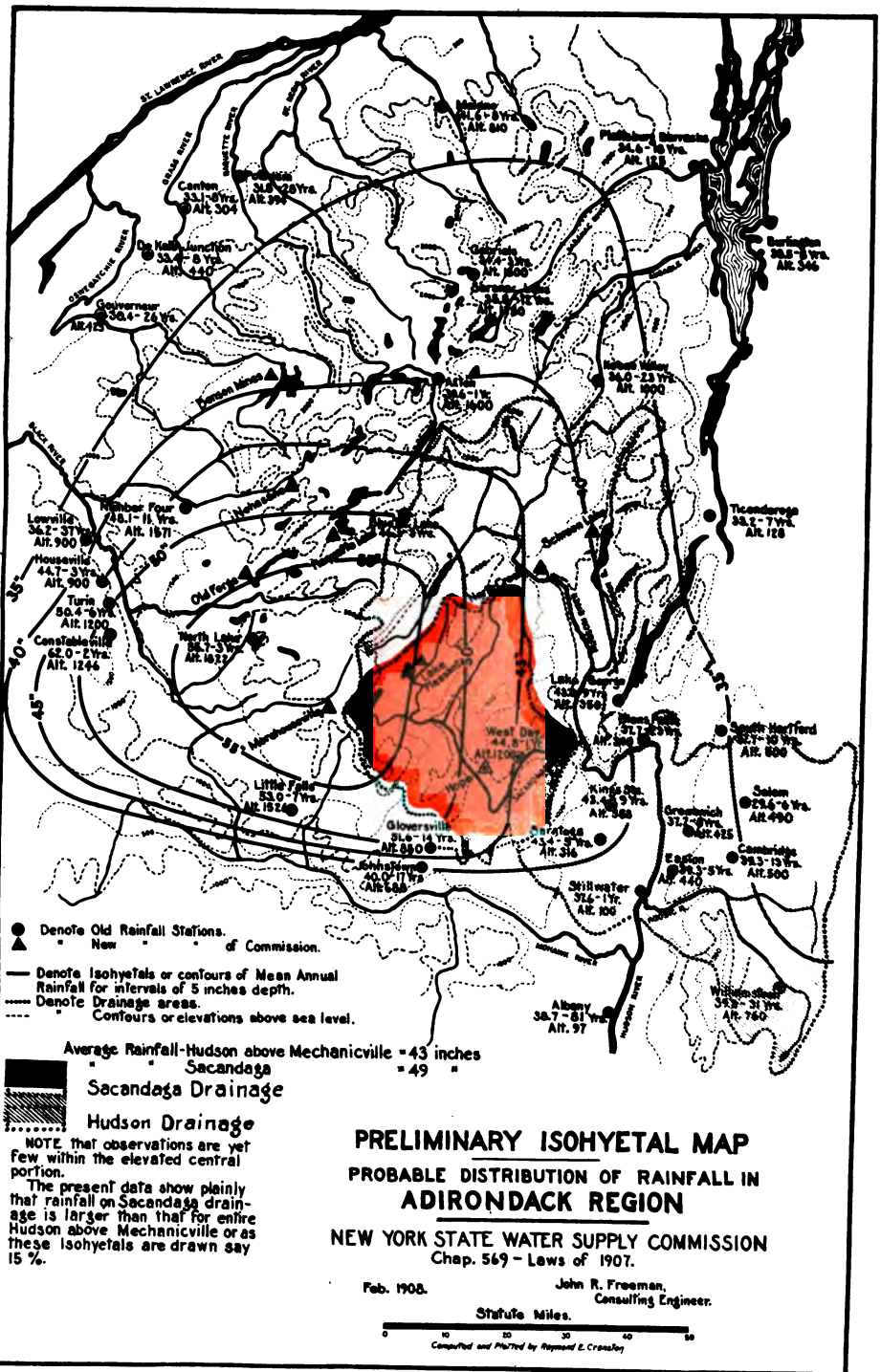

St. Lawrence River
Oswegatchie River
Oswegatchie River
Grass River
Raquette River
Canton
33.1 - 6 Yrs.
Alt. 304
Potsdam
34.8 - 28 Yrs.
Alt. 394
Malone
Alt. 6 - 5 Yrs.
Alt. 840
Plattsburg Barracks
34.6 - 16 Yrs.
Alt. 128
De Kalb Junction
33.4 - 8 Yrs.
Alt. 440
Ogdensburg
37.4 - 3 Yrs.
Alt. 1000
Gouverneur
36.4 - 26 Yrs.
Alt. 425
Burlington
38.2 - 9 Yrs.
Alt. 346
Keene Mines
Adirondack
Alt. 1400
Keene Valley
34.0 - 23 Yrs.
Alt. 1000
Black River
Lowville
34.2 - 37 Yrs.
Alt. 900
Number Four
48.1 - 11 Yrs.
Alt. 1871
Ticonderoga
38.2 - 7 Yrs.
Alt. 128
Houseville
44.7 - 3 Yrs.
Alt. 900
Old Forge
Turin
36.4 - 6 Yrs.
Alt. 1200
Constableville
62.0 - 2 Yrs.
Alt. 1246
North Lake
36.1 - 3 Yrs.
Alt. 1821
Lake George
43.2 - 7 Yrs.
Alt. 366
West Day
44.8 - 1 Yr.
Alt. 1200
Mohawk River
Little Falls
53.0 - 1 Yrs.
Alt. 1524
Gloversville
31.6 - 14 Yrs.
Alt. 850
Johnstown
40.0 - 11 Yrs.
Alt. 648
Saratoga
43.4 - 9 Yrs.
Alt. 316
Kings Bridge
43.4 - 3 Yrs.
Alt. 388
Greenwich
37.2 - 9 Yrs.
Alt. 425
South Hartford
32.1 - 10 Yrs.
Alt. 800
Salem
23.6 - 6 Yrs.
Alt. 490
Cambridge
38.3 - 13 Yrs.
Alt. 500
Easton
38.3 - 5 Yrs.
Alt. 440
Stillwater
37.6 - 1 Yr.
Alt. 100
Albany
38.7 - 81 Yrs.
Alt. 97
Hudson River
Williamstown
34.2 - 31 Yrs.
Alt. 760
Denote Old Rainfall Stations.
" New " " of Commission.
Denote Isohyetals or contours of Mean Annual Rainfall for intervals of 5 inches depth.
Denote Drainage areas.
" Contours or elevations above sea level.
Average Rainfall-Hudson above Mechanicville = 43 inches
" " Sacandaga = 49 "
Sacandaga Drainage
Hudson Drainage
NOTE that observations are yet few within the elevated central portion.
The present data show plainly that rainfall on Sacandaga drainage is larger than that for entire Hudson above Mechanicville or as these Isohyetals are drawn say 15 %.
PRELIMINARY ISOHYETAL MAP
PROBABLE DISTRIBUTION OF RAINFALL IN
ADIRONDACK REGION
NEW YORK STATE WATER SUPPLY COMMISSION
Chap. 569 - Laws of 1907.
Feb. 1908.
John R. Freeman,
Consulting Engineer.
Statute Miles.
0 10 20 30 40 50
Computed and Plotted by Raymond E. Crosslay

PLATE 10

AVERAGE MONTHLY RUN OFF IN INCHES DEPTH ON DRAINAGE AREA OF HUDSON RIVER AT MECHANICVILLE, FOR YEARS 1888–1907, INCLUSIVE.

Arranged in order of dryness.

(Corrected for Canal Diversion, May to November, Inclusive.)

Catchment area = 4,500 *square miles.*

MONTHS IN ORDER OF DRYNESS.	1888.		1889.		1890		1891.		1892.		1893.	
	Inches run off		Inches run off.		Inches run off.		Inches run off.		Inches run off.		Inches run off.	
1	July	0.44	Sept.	0.54	July	0.55	Oct.	0.43	Oct.	0.77	July	0.70
2	Aug.	0.49	Feb.	0.89	Aug.	0.57	Sept.	0.56	Sept.	1.15	Jan.	0.82
3	Sept.	0.76	Oct.	1.01	Feb.	1.83	July	0.65	Aug.	1.46	Nov.	0.95
4	Feb.	0.89	Aug.	1.14	June	1.88	Aug.	0.73	Nov.	1.94	Dec.	1.03
5	Oct.	1.23	July	1.52	Sept.	2.24	Dec.	0.83	Feb.	2.22	Oct.	1.04
6	June	1.27	June	1.75	Nov.	2.31	June.	0.84	Dec.	2.27	Feb.	1.09
7	Jan.	1.62	Nov.	2.01	Oct.	2.41	Nov.	1.06	July	2.43	June	1.24
8	Mar.	1.75	Mar.	2.12	Mar.	2.85	May	1.47	Mar.	2.80	Aug.	1.33
9	Dec.	2.05	May	2.32	Jan.	2.89	Jan.	2.12	June	3.13	Sept.	1.75
10	Nov.	2.69	Dec.	2.57	Dec.	3.39	Feb.	2.70	Jan.	4.83	Mar.	2.11
11	April	5.26	Jan.	2.81	April	3.73	Mar.	4.55	May	5.08	April	4.44
12	May	5.51	April	3.39	May	4.64	April	4.97	April	5.35	May	5.76

AVERAGE MONTHLY RUN OFF OF HUDSON RIVER AT MECHANICVILLE, 1888–1907 — (*Continued*).

MONTH.	1894.		1895.		1896.		1897.		1898.		1899.		1900.	
	Inches run off.		Inches run off.		Inches run off.		Inches run off.		Inches run off.		Inches run off.		Inches run off.	
1	Sept.	0.52	Sept.	0.70	Aug.	0.68	Oct.	0.70	July	0.69	Aug.	0.41	Sept.	0.52
2	Aug.	0.68	July	0.71	Sept.	0.76	Sept.	0.73	Sept.	1.01	Sept.	0.56	Oct.	0.59
3	July	0.86	Oct.	0.74	July	0.77	Feb.	0.90	June	1.35	July	0.67	July	0.65
4	Oct.	0.99	June	0.75	Oct.	1.10	Jan.	1.03	Aug.	1.35	June	0.70	Aug.	0.74
5	Feb.	1.12	Feb.	0.82	Feb.	1.12	Dec.	1.77	Feb.	1.56	Oct.	0.72	June	1.06
6	Nov.	1.63	Jan.	0.99	May	1.23	Aug.	2.16	Jan.	1.97	Feb.	1.22	Nov.	1.29
7	Jan.	1.73	Aug.	1.05	June	1.23	Nov.	2.52	Oct	2.07	Dec.	1.40	Jan.	1.50
8	June	1.81	Mar.	1.08	Jan.	1.74	July	2.79	Nov.	2.34	Nov.	1.63	Dec.	1.86
9	Dec.	1.85	Dec.	1.12	Dec.	2.79	June	2.99	May	2.88	Jan.	1.71	Mar.	1.98
10	May	1.99	May	1.81	Nov.	2.87	May	3.09	April	3.40	Mar.	2.47	May	2.35
11	April	2.76	Nov.	2.13	Mar.	3.49	Mar.	3.13	Dec.	3.67	May	2.54	Feb.	2.88
12	Mar.	3.78	April	5.91	April	6.20	April	4.73	Mar.	5.18	April	5.86	April	5.60

AVERAGE MONTHLY RUN OFF OF HUDSON RIVER AT MECHANICVILLE, 1888–1907 — (*Concluded*).

MONTH IN ORDER OF DRYNESS.	1901. Inches run off.		1902. Inches run off.		1903. Inches run off.		1904. Inches run off.		1905. Inches run off.		1906. Inches run off.		1907. Inches run off.		Average 20 years.
1	Feb	0.67	Sept.	0.95	May	0.95	July	(0.96)	Feb.	0.82	Sept.	0.81	Aug.	.45	0.662
2	Jan.	0.79	Jan.	(0.99)	Sept.	1.07	Nov.	1.20	Dec.	1.00	Oct.	0.91	July	1.00	0.824
3	July	0.96	Feb.	1.58	July	1.30	Aug.	(1.26)	Aug.	1.49	Aug.	0.94	Feb.	1.02	1.059
4	Nov.	0.97	June	1.61	Nov.	1.48	Dec.	1.36	Jan.	1.56	Nov.	1.32	Sept.	1.29	1.192
5	Sept.	1.05	Nov.	1.63	Aug.	1.56	Jan.	1.49	Oct.	1.60	July	1.53	June	1.49	1.381
6	Oct.	1.13	Aug.	1.66	Jan.	1.80	Feb.	1.64	July	1.81	Feb.	1.77	Oct.	2.41	1.613
7	Aug.	1.23	Oct.	1.81	Dec.	2.11	Sept.	1.70	Nov.	(1.94)	Dec.	(2.01)	Mar.	2.41	1.764
8	Dec.	1.36	May	2.08	June	2.15	June	1.73	May	2.14	Mar.	2.31	Jan.	2.59	1.996
9	June	1.98	Dec.	2.16	Feb.	2.28	Oct.	(2.70)	June	2.39	June	2.35	Dec.	3.01	2.287
10	Mar.	2.00	July	2.33	Oct.	2.64	Mar.	2.83	Mar.	2.41	Jan.	2.39	May	3.50	2.716
11	May	3.04	April	3.77	April	3.47	May	3.46	Sept.	3.03	May	3.49	Nov.	3.53	3.559
12	April	7.03	Mar.	6.36	Mar.	7.92	April	5.14	April	5.64	April	5.11	April	4.16	5.418
															24.471

POWER FROM SACANDAGA STORAGE, FIRST STAGE.

Increased Power at Present Hudson Plants if Sacandaga Reservoir be Used Solely for Benefit of Hudson River.

The mass curves show that at least twenty-two inches depth per year on watershed could have been drawn in the dryest period.

Twenty-two inches stored and released (=1.833 feet) is equivalent on 1,050 square miles of watershed to $\left.\begin{array}{l}\dfrac{1{,}050 \times 5{,}280 \times 5{,}280 \times 1.833 \text{ feet}}{365 \text{ days} \times 24 \text{ hrs.} \times 3{,}600 \text{ sec.}} = 1{,}703 \text{ c. f. s.}\\ \dfrac{1{,}050 \times 5{,}280 \times 5{,}280 \times 0.0833}{30.44 \times 24 \times 3{,}600} = 927 \text{ c. f. s.}\end{array}\right\}$ one inch run off from 1,050 square miles (Sacandaga) per month =

on 3,450 square miles of drainage above Mechanicville exclusive of Sacandaga $= \dfrac{3{,}450 \times 5{,}280 \times 5{,}280 \times 0.0833}{30.44 \times 24 \times 3{,}600} = 3{,}047$ c. f. s.

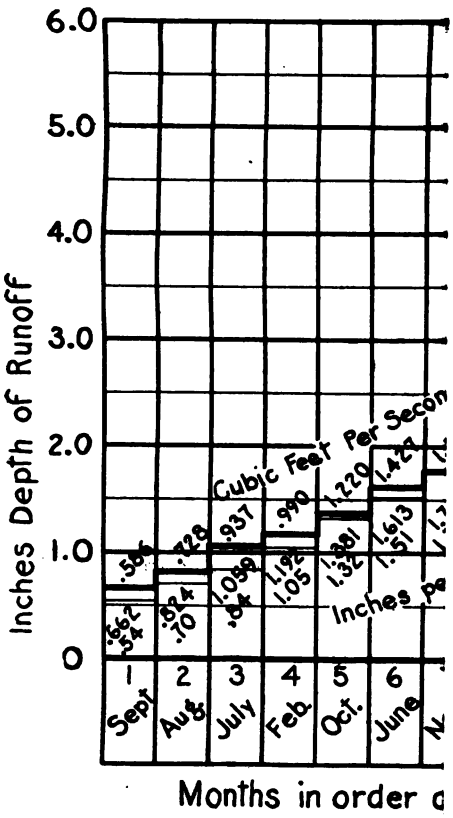
SACANDAGA STORAGE, FIRST STAGE OF DEVELOPMENT — COMPUTATION OF POWER DERIVED FROM THE STORED WATER, PER FOOT OF FALL.

Month in order of dryness.	Name of month oftenest in this order.	Yield of entire watershed in inches.	Flow in c. f. s. for all except Sacandaga. 3,450 sq. m. x3047.	Cu. ft. sec. drawn from Sacandaga. storage.	Equiv. inches drawn storage Sacandaga.	Total flow at Mechanicville. c. f. s.	Present Sacandaga flow, 1050. sq. m.	Increase of Sacandaga flow. c. f. s.	24 hour 7 day horse power from increased flow on 1 ft. fall at 75% efficiency.
1.....	September.....	.67	2,050	4,450	4.80	6,500	625	3,825	325.5
2.....	August.....	.81	2,480	4,020	4.34	6,500	755	3,265	277.8
3.....	July.....	1.06	3,230	3,270	3.53	6,500	984	2,286	194.5
4.....	February.....	1.18	3,620	2,880	3.11	6,500	1,100	1,780	151.5
5.....	October.....	1.37	4,190	2,310	2.49	6,500	1,270	1,040	88.5
6.....	June.....	1.57	4,790	1,710	1.84	6,500	1,460	250	21.3
								12,426	*1,059.1
7.....	November.....	1.73	5,270	1,230	1.33	6,500	1,600	—370	
8.....	January.....	1.96	5,990	510	.55	6,500	1,820	—1,310	
9.....	December.....	2.28	6,970	.....	.....	6,970	2,120	—2,120	
10.....	March.....	2.67	8,150	.....	.....	8,150	2,480	—2,480	
11.....	May.....	3.56	10,850	.....	.....	10,850	3,300	—3,300	
12.....	April.....	5.48	16,710	.....	.....	16,710	5,080	—5,080	
					21.99			—14.660	

*Average for six months, 176.52.

AVERAGE MONTHLY
FOR 20 YEA
Months Arranged

1.0 inch of runoff per month
$$\frac{5280 \times 5280}{12 \times 30.44 \times 86400} = 0.885$$



1.0 inch of runoff per month
$$\frac{0.885 \times 62.4 \times 1.0 \times 80\%}{550} = .0$$
$$= 8$$

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6th. dryest month. (21.3)
1,780
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POWER FROM SACANDAGA STORAGE, FIRST STAGE.

Increased Power at Present Hudson Plants if Sacandaga Reservoir be Used Solely for Benefit of Hudson River.

The mass curves show that at least twenty-two inches depth per year on watershed could have been drawn in the dryest period.

In the foregoing computation the Sacandaga yield is taken strictly proportional to the Hudson yield measured at Mechanicville — it is probable that the Sacandaga drainage yields 15 per cent. more than this.

INCREASE OF HUDSON RIVER POWER FROM SACANDAGA STORAGE, FIRST STAGE.

Increased Power at Present Hudson Plants if Sacandaga be Used Solely for Benefit of Hudson River.

Twenty-four hour, 7 day horse power with 75 per cent. efficiency of turbine.

Computation of Increased Power at the Several Sites.

	Working head.	Added in dryest month. (325.5)	2nd. dryest month. (277.8)	3rd. dryest month. (194.5)	4th. dryest month. (151.5)	5th. dryest month. (88.5)	6th. dryest month. (21.3)
Palmer's Falls	84	27,340	23,330	16,340	12,730	7,430	1,780
Spiers Falls	75	24,410	20,830	14,590	11,290	6,640	1,600
Feeder Dam	18	5,860	5,000	3,500	2,730	1,590	380
Glens Falls	38	12,370	10,560	7,390	5,760	3,360	810
Sandy Hill	70	22,780	19,450	13,610	10,600	6,200	1,490
Baker's Falls } Fort Edward }	18	5,860	5,000	3,500	2,730	1,590	380
Fort Miller	9	2,930	2,500	1,750	1,360	800	190
Saratoga	18	5,860	5,000	3,500	2,730	1,590	380
Stillwater	6	1,950	1,670	1,170	910	530	130
Mechanicville	18	5,860	5,000	3,500	2,730	1,590	380
Mechanicville, elec	19	6,180	5,280	3,700	2,880	1,680	400
Troy	7	2,280	2,060	1,360	1,060	620	150
	380	123,680	105,680	73,910	57,510	33,620	8,070

Total	402,470
Average power added at all sites for 6 dry months	67,080

Check average = 380 x 176.52 = 67,080 horse power.

Or the Sacandaga storage as thus used in First Stage can be made to add 67,000 horsepower of 24 hour, 7-day power throughout the dryest six months of the average year at the sites already developed on the Hudson.

Granting that the Sacandaga yields 15 per cent. more runoff per square mile, the increased power will be correspondingly larger than is here computed.

There is said to be a total undeveloped fall of about 70 feet between Spier's falls and the feeder dam at Glens Falls. The additional power upon this would be substantially the same as figured above for Sandy Hill and Baker's Falls, and would therefore add 70/380 or 18.4 per cent. to the totals figured above, making the total average addition in the dryest month about 146,500 horse power, and in the dryest six months about 79,500 horse power.

POWER FROM SACANDAGA STORAGE, SECOND STAGE.

Increased power on present Hudson river plants if *constant draft of* 1,700 *c. f. s.* be drawn from Sacandaga reservoir *for new power plant near Hadley.*

Computation of Power from the Stored Water, Per Foot of Fall.

Number of month in order of dryness.	Name of month oftenest in this order of dryness.	Average natural yield of Sacandaga in proportion to drainage from Mechanicville gagings.	Regulated yield.	Increase in main river due to regulation.	H. P. of increased flow in 1 ft. fall at 75 per cent. efficiency. x .08509.
1	September	625	1,700	1,075	91.48
2	August	755	1,700	945	80.40
3	July	984	1,700	716	60.92
4	February	1,100	1,700	600	51.06
5	October	1,270	1,700	430	36.58
6	June	1,460	1,700	240	* 20.42
7	November	1,600	1,700	100	8.51
					†349.37
8	January	1,820	1,700	—120	.....
9	December	2,120	1,700	—420	.....
10	March	2,480	1,700	—780	.....
12	May	3,300	1,700	—1,600	.....
12	April	5,080	1,700	—3,380	.....

* Average six months, 56.81. †Average seven months, 49.91.

POWER FROM SACANDAGA STORAGE, SECOND STAGE.

Increased power on present Hudson river plants if *constant draft of* 1,700 *c. f. s.* be drawn from Sacandaga reservoir *for new power plant near Hadley.*

Computation of Increased power at the Several Sites.

	Wkg. head.	Added in dryest mo. (91.48)	2d. (80.40)	3d. (60.92)	4th. (51.06)	5th. (36.58)	6th. (20.42)	7th. (8.51)
Palmers Falls	84	7,680	6,750	5,120	4,290	3,070	1,720	710
Spiers Falls	75	6,860	6,030	4,570	3,830	2,740	1,530	640
Feeder Dam	18	1,650	1,450	1,100	920	660	370	150
Glens Falls	38	3,480	3,050	2,310	1,940	1,390	780	320
Sandy Hill, Bakers Falls	70	6,400	5,630	4,260	3,570	2,560	1,430	600
Fort Edward	18	1,650	1,450	1,100	920	660	370	150
Fort Miller	9	820	720	550	460	330	180	80
Saratoga	18	1,650	1,450	1,100	920	660	370	150
Stillwater	6	550	480	360	310	220	120	60
Mechanicville	18	1,650	1,450	1,100	920	660	370	150
Mechanicville Elec	19	1,740	1,530	1,160	970	680	390	160
Troy	7	640	560	430	350	260	140	60
	380	34,770	30,550	23,160	19,400	13,890	7,770	3,230

Average 7 months ..... 380x49.91=18,970
Average 6 months ..... 380x56.81=21,590
Total 7 months 132,770
Total 6 months 129,540

Or the storage as thus used in second stage, can be made to add an *average of* 18,970 *net* 24*-hour, 7 day horse power for dryest seven months and* 21,590 *for dryest six months* at the several sites already developed.

At the undeveloped fall of about seventy feet below Spier's falls the additional power would be about the same, month by month as is reckoned above for Sandy Hill.

SCOPE OF THE SACANDAGA SURVEYS.

This has already been outlined on page 35 and the series of 25 maps there presented in small scale photographic reduction from the original sheets tell the story of scope and completeness of the survey so fully that little description needs to be added.

The whole area to be covered somewhat exceeds 60 square miles of which it is proposed to flood 42 by the reservoir.

A large part of the bottom of the proposed reservoir consists of flat meadow and wooded swamp lands, but the shores are mostly rather steep irregular slopes which in many cases are covered with brush making progress of survey slow and difficult.

Obviously the work of first importance was the obtaining of data for locating the elevation of the flow line, the position of the future shore line in relation to existing structures and therefore a strip varying from ⅛ to ¼ mile in width aggregating nearly 16 square miles in area, was first surveyed for almost the entire circumference of the basin. Traverses were run and sufficient levels taken to obtain in a general way the lay and general elevation of the bottom land to the extent of about 25 square miles more. In addition about 2 square miles of area down stream from the dam was surveyed in connection with the power-house studies.

Beside this a rough survey was nearly completed around the Hadley Reservoir on the Hudson which will serve as a basis for future extension and which serves to locate the Hadley dam and to show the property in Luzerne and Hadley that would be affected. About 197 miles of traverses were run on the Sacandaga surveys and about 24 miles on the Hadley surveys.

One hundred and fifty-five miles of check levels were very carefully run for establishing benches and 214 permanent bench marks established. During the course of the survey the elevations and positions of about 60,000 points were determined for use in mapping.

Twenty-six test borings, aggregating 1,304 feet in depth, were put down by the force under Mr. Ropes and 122 samples of the substrata preserved in glass bottles for future reference. Severe winter weather and snow caused a suspension of field work on December 10, after which the efforts of the force were concentrated on map making, designing and estimating.

PROPOSED PLAN OF SACANDAGA WORKS.

The main features are:

1. A dam at Conklingville raising the water about 55 feet above its present level.

2. A lake of about forty square miles at high water formed by the flooding of the valley, due to this dam.

3. A spillway over solid rock off to one side of the dam and sufficient for carrying the greatest conceivable flood.

4. Sluiceways through which as high as 6,000 cubic feet per second may be discharged, these sluices and their intake forming the head works of a future power tunnel in the ledge.

The above comprise the first instalment, sufficient for giving the Hudson at Mechanicville a uniform flow during the dry six months of the year, never less than 6,500 cubic feet per second.

5. At some later date, a power tunnel under the mountain toward the power house near Hadley, about two miles in length and about twenty feet in diameter.

6. A power house equipped with four or five units for regular use, each of 10,000 kilowatts capacity and one spare unit of same size, the whole being designed to supply about 60,000 electrical horse power to consumers during ordinary working hours, every working day in the year, as per com putation on page 147.

7. A tail race about a mile and a quarter in length and formed mainly by deepening the present channel of the Sacandaga river from its mouth upwards, by means of dredging. Borings show that beneath the river bed the material for about fifty feet or more in depth is sand, shingled over with a layer of boulders and cobble stones.

Borings and test pits and studies of land values are not yet complete enough to show precisely the economic limits, but what I have aimed at is the maximum utilization that this site will afford, and subject to revision, it is now proposed that the flow line in extreme floods should seldom or never rise above contour 773 above sea level, this being with a depth of three feet over a spillway with crest at elevation 770. It is proposed that the lake should never be drawn more than thirty feet below the spillway level. It is possible that the further studies may lower the height of flow line five feet, and perhaps more.

In the early years before the power house is built, while the reservoir is used solely for the benefit of the power sites along the Hudson, all the way from Palmers Falls to Troy, the equivalent of a yearly average discharge of 1,700 feet per second (or more probably 1,900 c. f. s.) every hour in the year which such a reservoir is found capable of supplying, would be nearly all discharged within the six dry months, thus averaging about 3,100 cubic feet per second for these months, but in the dryest week of a dry year, averaging as high as 5,000 cubic feet per second, and varying month by month as needed to supplement the flow of the main Hudson, as shown in table on page 152.

In the later years after the power house is built, it is proposed to draw the reservoir at substantially a uniform rate throughout the year, regulating the rate of draft from hour to hour mainly for the benefit of this Sacandaga

power house, and a few years later or *as soon as the Sacandaga power house was fully utilized, building other reservoirs on the upper Hudson above North Creek and at Hadley and upon the Schroon, which would in combination with the regular draft from Sacandaga reservoir maintain as great or a greater flow for all the mills below Hadley, than the* 6,500 *cubic feet per second provided for in the first stage while the Sacandaga reservoir was devoted solely to the use of the down river mills* and therefore kept nearly shut off for six months in the year.

It is planned to take the whole head of the new Sacandaga Lake into the power-house, with the exception of what is lost by friction in the tunnel, and is proposed to make the tail race deep enough so that the power-house will have the benefit of the Hudson level below Hadley, as nearly as the necessary friction loss in this tail race channel will permit.

The varying head in the lake will involve the use of a tunnel under pressure.

A surge shaft and tank at the lower end of this tunnel is designed so as to prevent any large oscillations of head when rate of power draft is suddenly changed, and by this means, high velocities in the tunnel may be used during peak loads.

The general layout is shown in drawings of plates Nos. 11 to 16.

The average elevation in the lake would be 765 feet, for as is shown in the depletion diagram, plate 4 and in the description on pages 113 to 116 this reservoir would seldom be drawn down more than ten feet at the extreme low point of an ordinary year.

And allowing a total friction loss under average working conditions of fifteen feet in head-works, tunnels and penstocks, this leaves for the working head at the power-house, elevation 750 feet.

Assuming that the tail race can be dredged economically in the sandy material shown by the borings, of such ample size that there will be a loss of only about one foot per 1,000 feet or of seven feet between the turbine pit and the Hudson river, which at the confluence has ordinarily an elevation of 548, this gives as the working level in the turbine pit an elevation of 555 feet above sea.

The working head will therefore be $750 - 555 = 195$ feet.

To allow for possibilities of the lake level having to be lowered, or of the tail race level being higher, we call the net fall ten feet less than just estimated, on 185 feet.

Each ten feet difference in the net fall makes a difference, including 40 per cent. load factor and other factors as above, of about 2,700 horse power at the consumers' end, and *adds nothing in cost of tunnel or turbines or cost of power-house or in the daily cost of attendance and maintenance* and adds substantially nothing to cost of transmission plant, and if this electrical power under the 40 per cent. load factor is worth no more than twenty dollars per horse power at the consumers' motor, the yearly value of each ten feet additional head would be $54,000, *which capitalized at* 6 *per cent. is* $900,000, *or capitalized at* 8 *per cent. is* $675,000. And this is the limit to the extra expense that could be profitably incurred in gaining ten feet of extra head. This shows the importance of so designing the plant as to secure the utmost fall on the turbines by means of a high reservoir level and also by a deeply-dug tail race channel.

The preliminary designs have been made for a tunnel lined with concrete, of the ordinary horse-shoe aqueduct section, and equivalent in area to a circle of twenty feet in diameter.

A preliminary study had made so plain the importance of obtaining the greatest possible elevation of flow line for the purpose just mentioned and in order that sufficient storage could be had to carry over from a year of large rain fall for use in a year of small rain fall and yet have enough to permit at all times keeping the swampy bed of the basin well covered, that surveys to determine the maximum height of flow line permissable were made in great detail.

Contour lines at all the villages bordering the lake were traced out and all dwellings and other buildings were located out as far as could be affected by the highest possible flow line, and plans for future reference were prepared, as has been already set forth in items 9, 10 and 11 on pages 35 and 36. There land plans form Series "C." Small scale photo-engravings are appended, at end of report, that the information obtained may not become buried from use.

The accompanying drawings, plates 11 to 16, show the outlines of the proposed dam and power-house structures.

BORINGS AT DAM SITES.

Wash borings were promptly undertaken at the several sites which appeared most favorable for a dam. Owing to the lateness of the season the number of holes put down was much less than desired and the contractor who undertook making diamond drill borings to bed rock suffered from a series of financial misfortunes and mechanical accidents, such that he succeeded in putting only a single hole, to the depth of about 100 feet, without reaching ledge.

Mr. Parsons, engineer of the Hudson River Power Co., kindly gave us results of a few similar borings that he had put down.

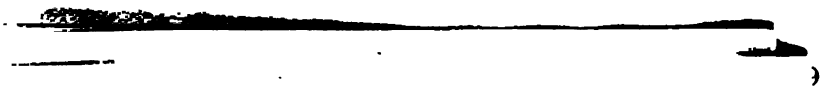
Samples from these borings have been preserved and forwarded to the office of the State Water Supply Commission at Albany.

A few representative specimens were forwarded for expert examination; one set to one of the experts of the Board of Water Supply, who was engaged in making many hundred deep borings on Long Island; and another set of the same to Prof. W. O. Crosby of Boston, Consulting Geologist to the Metropolitan Water Board of Boston and to the Board of Water Supply of New York city. The reports follow on the next page.

From my personal examination and from the more complete daily examinations of Mr. Ropes as the work progressed, I believe that all borings thus far made concur in showing the feasibility and safety of the type of dam proposed at this site, but before becoming definitely committed to so important a work, many more borings should be taken.

All borings concur in showing that a deep buried gorge more than a hundred feet deep exists all along under the river bed.

The following is result of expert geological examination of a few of the samples.



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CLASSIFICATION OF SAMPLES FROM TEST PITS AND BORINGS AT SITE OF PROPOSED DAM ON THE SACANDAGA RIVER, N. Y.

By Walter E. Spear, Division Engineer, B. W. S., Babylon, N. Y.

Sample No.	Color.		Character.	Percentage of This Material						Mechanical Analyses.		
				Gravel.		Sand.						
	Wet.	Dry.		Coarse.	Fine.	Coarse.	Medium.	Fine.	Superfine.	Effective size.	60% finer.	Uniformity coefficient.
										Mili meters.		
2.....	Rich yellow.	Rich yellow.	Wash sample. Medium and fine micaceous quartz sand.....	.....	....	.....	37.9	62.1	....	0.21	0.36	1.71
5*.....	Grayish black	Light yellowish gray.	Wash sample, 109 feet to 185 feet. Gray superfine sand and rock flour.	.....	....	.....	.....	32.8	....	.....	0.09	.....
5-A*.....	Brown.....	Light gray..	Wash sample. Light gray micaceous rock flour with very small amount of superfine sand.....	.....	....	.....	.....	4.4	....	.....	.....	.....
Test pit.....	Brown yellow.	Yellowish gray, bakes red.	Dry sample. Yellowish gray; dry, compact and partially cemented mixture of fine gray, coarse and medium sand with superfine sand; breaks up slowly in water to brown mud.....	2.0	2.0	15.9	21.9	44.1	14.1	0.08	0.37	4.63
Test pit "D"...	Brown.....	Yellow gray, bakes yellow gray.	Dry sample. Same as test pit "B".....	3.7	3.0	21.9	24.2	39.1	8.1	0.115	0.47	4.09

*Too fine for our sieves.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BOSTON, MASS., GEOLOGICAL DEPT.

Classification of a Few Samples from Sacandaga Dam Site.

February 27, 1908.

MR. JOHN R. FREEMAN, *Consulting Engineer, Providence, R. I.*:

MY DEAR SIR.— I have examined the samples of earth from the proposed dam site on the Sacandaga river sent me by Mr. Ropes, and beg to report on the same as follows:

Test-pits B and D (on southerly side of dam site B). These two samples are essentially identical. The material is clearly a rather sandy till or bowlder clay, derived by glacial erosion from a granitic bedrock. It is of a highly composite character — a heterogeneous mixture of particles ranging in size from gravel to rock flour and clay, the finer grades of sand and rock flour largely predominating. The proportion of true clay is quite small, but still sufficient to yield a firm mass by drying. Although, to the naked eye, the material appears dense or non-porous, it absorbs water rapidly on partial immersion, showing that the interstices are mainly capillary in size, and not sub-capillary, as would be the case in a true clay. It cannot, therefore, be described as impervious; but, I believe, nevertheless, that actual trial, for which these samples are insufficient, would show that the filtration rate is low. Abundant experience has shown that this association of a low filtration rate with a marked degree of perviousness is not unusual, and that it is especially characteristic of rock flour and sandy till.

By virtue of its sandy and essentially non-clayey character, this till would yield readily to a stream of water, and thus be found well adapted to excavation and transportation by the hydraulic method. In fact, it may be doubted if earth more suitable for use in this way could be found; since a larger proportion of clay would add to the resistance to excavation without insuring a larger proportion of clay in the re-deposited material.

The marked buff color of these samples is due to oxidation, and indicates that they are probably from near the surface. Or, if from a considerable depth, the color affords additional proof of unusual perviousness for till. The general effect of oxidation, aside from change of color from gray to buff, is to cement the particles and yet leave the structure more open.

Test-pit F at dam site D (adopted site) southerly side. This sample is essentially similar to the preceding, except that the color is gray instead of buff and it has, presumably, come from a greater depth, or at any rate from below the zone of oxidation.

Test-pit G, dam site D, southerly side. This sample is also essentially similar to the preceding, except that it is distinctly more sandy, containing hardly more than a trace of clay. An approximate analysis shows:

Gravel	50 per cent.
Coarse and medium sand	25 per cent.
Fine sand	15 per cent.
Superfine sand and rock flour	10 per cent.

This material must have suffered a considerable loss of clay and rock flour by the washing action of water at the time of its deposition. But it is probable that in spite of this its highly composite character gives it a low filtration rate. The buff color is less indicative as to depth than for samples B and D, because of the more sandy and permeable character. But for the angular and unworn forms of the stones, this might, if judged by so small a sample, be regarded as more properly gravel than till. Field observations are essential to the satisfactory classification of such materials.

Sample No. 5, on river margin at dam site D, from boring 185 feet deep represents ground from 109 to 185 feet below top of hole. This is essentially a mixture of superfine sand and rock flour (6, 7, 8) without clay. It is modified or washed drift which has been deposited in standing water and under conditions unfavorable to a low uniformity coefficient. Consequently a low filtration rate is a safe assumption. Under the conditions stated in previous report (six-inch column and ten-foot head), the filtration would quite surely fall below 500 and possibly below 100 cubic centimeters per hour. In this connection it would be of special interest to know whether this is a dry or a washed sample. To be conservative, I am assuming it to be the former. It is unoxidized (gray instead of buff); but this is what we should expect from its position, well below the water table. It is unoxidized; and its filtration rate must be very low, or practically zero. As a foundation for the proposed dam it may be accepted with entire confidence.

Very truly yours,
(Signed) W. O. CROSBY.

PROPOSED DAM.

After deep borings had shown no ledge in the river bed within economic reach, and that beneath the present river channel is a preglacial gorge perhaps 150 to 200 feet deep filled with fine sand, the preliminary estimates indicated the best and most economical solution to be a great earth dam of almost unprecedented thickness combined with a new spillway channel constructed over the ledge at one side.

Four sites designated as A, B, C, and D on plate No. 11 were studied and the preliminary survey and the comparative estimates indicate that D is the best. The type and general dimensions proposed are shown in plate No. 12.

It would doubtless be entirely safe to make the dam much thinner and with much less height above the flow line than I have shown in this preliminary plan but liberal dimensions are adopted for purpose of estimate until later borings shall show character of ground more completely, and because the hydraulic-fill type is novel in this part of the country. The excavation and placing of material by the hydraulic sluicing process is so very cheap per cubic yard that one can afford to be generous in the quantity used.

A concrete core wall is added in deference to the popular belief that this would be one more precaution for safety, and below this core, triple lay sheet piling would be sunk perhaps forty feet deep in a line entirely crossing the gorge.

The excessive thickness of about 230 feet at flow line, the thickness of about 1,000 feet on present river bed, and the super-elevation of twenty-five feet above the spillway are all excessive and preclude that the dam should be cut through malice, or overtopped by a cloud-burst or that percolation beneath it can cause trouble.

The spillway crest is given the ample length of over 800 feet, or more than has been given to dams on the main river, at some of which the drainage area is four times as great as here, and this notwithstanding the great effect of a lake of forty-two square miles area in holding back a flood.

The discharge channel over the ledge has purposely been given a very high and increasing declivity and a straight course with smooth walls, in order that by no chance can it become gorged. The large quantity of ledge that will be excavated in forming this spillway, together with broken rock from the tunnel can be used to form a very ample but cheap riprap for the dam.

In brief, it has been planned to provide most ample factors of safety in all features of the design.

To care for freshets during the period of dam building, it is proposed to begin this work by driving a tunnel about twenty-five feet in diameter through the spur of ledge and at as low an elevation as practicable, through which all summer ordinary floods could pass; and to provide against the washing out of the partially completed earthwork in even a most severe flood, by confining the work in the river bed between two temporary coffer dams somewhat more than 1,000 feet apart built of cribs of rough logs filled with stone, planked on their upstream faces, each line of this planking being connected to a line of deep sheet piling sunk by water jet. These coffer dams would be finally filled over and left within the finished structure, which would be given very flat slopes, about three feet of lean concrete would be used in topping out the steps of the high down-stream coffer, and for the down-stream

facing of the crib. The type of structure proposed has been many years in successful use on the Susquehanna and other rivers, but this one being of a temporary character could be more roughly built.

The upstream coffer would be about sixteen feet high and the down-stream about forty feet high — and in case of flood the space between would be expected to fill while the flood would pass off over the stepped overfall of the down-stream coffer dam — with no chance of cutting out any large portion of the earth already deposited upstream from it. It is believed the contingencies of log jams and of floating snags clogging the tunnel can be amply safeguarded.

The intake tower of reinforced concrete shown in outline in plate 13, would be built within a coffer dam in time of low water after the completion of the main structures while temporarily storing the river flow and would have its lowest gates so set that when carrying the normal rate of discharge the reservoir could not be drawn below about elevation 740.

Within the past year and a half I have had opportunity to study the process of earth dam building by hydraulic sluicing in California, Colorado and Mexico, the dams in the two localities last named being far larger structures and for much greater depth of water than proposed here and, subject to further exploration by test pits and borings, I believe the method can be used here to great advantage, and will give by far the cheapest and safest type of dam.

The accompanying drawings, plates 11 to 16 illustrate the general type and dimensions of the structures proposed and upon which the preliminary estimates of cost are based.

It is assumed that the power house would not be built until some years after the reservoir had been put in use for storage, and that the tunnel already described would serve for the discharge sluices and that it would be provided with gates and bulkhead at its lower end, from which it could be extended to the power-house.

Gates to be provided near its temporary end immediately below the dam, could be used to discharge any desired amount from the reservoir directly into river, without passing it through the power-house.

The proposed power tunnel probably involves some special difficulty in passing through wet earth at one or two short intervals of its length and at its lower end, but it is believed this sandy ground can be drained of the ordinary ground water temporarily while the work is in progress by driven wells of large size — closely spaced, so that only the ordinary problem of a tunnel in damp sand will be presented. It is planned that for these sections in earth the concrete lining would be of extra thickness and heavily reinforced by corrugated steel rods to withstand the water pressure. The lining of the tunnel where in rock would be of the ordinary type of concrete tunnel lining, without reinforcement.

The power-house can be given an abundantly safe foundation of concrete having deep lines of sheet piling under its edges, although the bed rock be a hundred feet below.

In view of the long tunnel line, special attention has been given to avoiding troublesome pressure waves while changing the output of power from time to time and the power house has been so located that an ample basin of about 200 feet diameter can be placed on the hill near it at the reservoir

level. Indeed the position and elevation of this hill finally controlled the selection of the power house site. The connecting surge pipes have been computed of size suitable to check oscillation and to give quick efficient governing of the turbines, without waste of water, and the length of the feeder penstocks has been carefully kept within the limits permitting quick governing without difficulty from momentum pressures.

ESTIMATES OF COST AND PROFIT.

MARCH 1, 1908.

At the time of selecting the Sacandaga project and the Portage project as being the two opportunities for water power development under State control that promised the best return, in a broad sense, of any of the possibilities found in a study of the maps and of previous reports, rough estimates were made which indicated a fair margin of profit to the State in both of these projects.

That these investments would be profitable also appeared reasonable in the case of the Sacandaga from the earnestness with which the Hudson River Power Company had sought control by the bonding of lands in the reservoir bed and through asking the approval of the Public Service Commission for a bond issue of some millions of dollars for financing the construction of a smaller Sacandaga reservoir and its proposed temporary dam.

In the Portage development, the reasonableness of a profit seemed assured from the estimates of cost by Mr. Rafter, published with the State Engineer's report for 1895, and from the earnestness with which it had been sought to revive the charter of the corporation formed some years ago for water power development at Portage.

I have myself hesitated to present estimates concerning the cost and probable profit, in this progress report, or until borings and test pits should further confirm the entire feasibility of the designs submitted, and until studies of flood control at Rochester, and in the broad valley above Rochester, should show what part of the burden could fairly be placed on those interests, and until studies of flood relief at Troy and Albany and studies of the improvement in navigation which would result from an increase of 4,000 or 5,000 cubic feet per second in the summer flow at Mechanicville should give some measure of the probable value of these benefits, and until the collection of data showing the benefits of freshening the polluted river above Poughkeepsie by a much larger summer flow.

On further consideration, it appeared plain that the questions of cost and profit are so vital to the attractiveness of these projects or to their feasibility in a commercial sense, that I have had the following estimates prepared.

They are intended to be made on a liberal basis as regards quantities, unit prices and contingencies, but it is to be clearly understood that they are made prior to the completion of the final studies and are subject to revision.

I will confess to some disappointment that the totals are so large, and that the cost per horse power, if all the burden is thrown on to the water power, is so much larger than the reputed cost of development at Niagara and sundry other power sites.

It is, however, natural that the sites presenting the greatest natural advantages in first cost should have been already developed, and that the developments of the future, as the remaining opportunities are successively availed of, will increase until the margin between the cost of water power and the cost of steam power is much smaller than at present.

It is commonly good practice, in a general estimate like this, to present only the results, in round numbers; but in the following, I have thought it well to present the figures in some detail, in order that it may be plain that details have been considered in reaching these figures, and in order that in these days of rapidly changing costs, it may be more easy some years hence for others skilled in the art to critically examine or revise these estimates.

SACANDAGA PROJECT.

COST OF RESERVOIR SITE.

The elevation of spillway is now proposed at 770 feet above sea level. Possibly opposition may lead to some sacrifice of efficiency, and it may become expedient to fix the spillway at elevation 765.

Little, if any, farming lands, woodland or pasture land lying 3 feet or more above the spillway crest would be appreciably injured by the back water from the reservoir, for it would be rare indeed that other than a winter freshet could rise 3 feet above the spillway level, for at this height above 20,000 cubic feet per second could be discharged (nearly 16,000 c. f. s. over spillway and about 4,000 c. f. s. thru sluices) equivalent to 20 c. f. s. per square mile, or to 0.71 inch in depth of run-off over entire watershed, in addition to which the rise of 3.0 feet in the lake level above the spillway crest would hold back nearly an inch in depth of run-off.

Perhaps once in each quarter century, or in each half century, a rise for a few hours to 5.0 feet above the spillway level would be had, but in the absence of hourly gage heights during a flood, for showing the form in which the Sacandaga flood-wave reaches Conklingville, no attempt has yet been made to compute the exact limit of height. The 5 foot depth over spillway, aided by open sluice gates, would pass about 36,000 cubic feet per second or 36 cubic feet per second per square mile, which is a large flow for a forest covered area of 1,050 square miles having lakes and swamp lands on its head waters. The land damages should therefore fairly be estimated to include lands lying below *contour 775.* In order to give ample margin of safety the dam and spillways are planned sufficient for a much greater flood than this.

To make sure of our surveys being sufficiently inclusive, the lands were surveyed and contours run up to elevation 780, and the following estimate is figured out to that limit altho plainly excessive in area.

The total area up to elevation 780 is 29,430 acres = 46.0 square miles.
The total area up to elevation 770 is 27,350 acres = 42.7 square miles.

Between 770 and 780	2,080 acres	3.3 square miles.

Among the courtesies extended to us by the Hudson River Electric Power Company was that of permission to copy their land maps and take note of values at which sundry parcels had been bonded. This corporation had for two or three years held options on a considerable part of the land up to or above the 770 contour, but mostly below the 750 contour.

Notwithstanding that much of this portion of the valley is in a decadent condition since the abandonment of tanneries and factories, and that the property owners in general appeared desirous of converting their lands and buildings into cash, we have in making the following valuation added 50 per cent. to the general scale of prices agreed on in the options just mentioned, to allow for the customary legal and other expenses and for the higher price that land bought or taken for public purposes appears to command. For the land between elevations 750 and 780, we have allowed a still more liberal estimate.

We thus find as total probable cost of reservoir lands to the State about $2,000,000, this embracing about 29,400 acres. The whole thus averages, including buildings, $68 per acre, but much of the land is swamp or brushland or sterile pasture.

During the progress of the surveys, inquiries were made of many residents in different neighborhoods, with a view to determining the actual values of typical parcels, as between a willing seller and an intending buyer.

The replies tended to show that the average selling values within the Sacandaga valley were:

Brush and pasture land about	$5 00 per acre.
Wood land	20 00 per acre.
Tillable land	30 00 per acre.

These prices would include the ordinary farm buildings.

An attempt was also made to learn the ratio of assessed value to market value by first obtaining the assessor's valuations and then viewing the property and making outside measurement and inspection of the buildings. About one-half the property had been gone over in this manner before the work was stopped by severe storms and deep snow.

In general, the town clerk stated the ratio of assessed value to fair market value as about two-thirds. The town clerk of Day gave no ratio. Comparison of the records with the statements of individuals and with the judgment of the engineer, so far as the work had progressed, would indicate the ratio to be more nearly one-fifth or one-sixth for farm property, one-third for village lots and buildings.

An enumeration and classification of the buildings within the Sacandaga reservoir limits, based on our maps and surveys, gives the following totals:

	Below elevation 770.	Between elevation 770 and 780.	Total.
Dwellings	447	127	574
Barns and outbuildings	611	132	743
Churches	1	3	4
Stores	4	3	7
Schools	4	1	5
Mills	9	1	10
Miscellaneous	7	0	7
	1,083	267	1,350

The average value of these buildings appears from our detail lists to be about $750 each On this basis the value of all the buildings would be 1350 x $750 = $1,012,500.

The value of the buildings situated between contours 770 and 780 is thus; 267 x $750 = $180,250.

The location of, say, two-thirds of all the buildings is, in general, near the shore of the proposed reservoir and in the majority of cases these could be moved back to new sites above the flow line without much trouble or expense.

This being the case, some proportion of the first cost of these buildings should be recovered during the progress of the work, but because of the uncertainty of the amount, no allowance for salvage on these buildings has been made in the total estimate of cost of land and buildings to be acquired by the State.

CLEARING AND GRUBBING SACANDAGA RESERVOIR.

Observations relative to the area and character of the brush and timber lands within the reservoir had been only about one-half completed, when severe winter weather covered the ground with snow and compelled the abandonment of the work. It is not, therefore, possible to do much more than make a guess at the remainder. From a study of our maps and a general knowledge of the country, it would appear that an assumption of 9,400 acres of land requiring clearing and grubbing will not be too liberal for purposes of a preliminary estimate A considerable proportion of this is scrubby brush and sprout land, comprising small white birch and alder growth, which if cut close to the ground will make grubbing unnecessary. The brush should be cut close and burned, from land of that character, for about $15 per acre.

In the Vly district there are several thousands of acres of woodland, covering low lands which are swampy and difficult of access, except when frozen over in winter or during extremely dry seasons. The trees in these woods are fairly large and lumbering operations will be difficult. Such land as this would cost from $80 to $100 for complete grubbing and clearing, but the lumber would have some value, and only a portion of this ground needs to be so thoroly cleared. Portions of these woodlands lie between elevations 725 and 730, or so low that if the reservoir is not to be drawn below the 740 level, the grubbing of stumps can be dispensed with wherever the depth at low water will not be less than five or ten feet, or on all ground at elevation 730 and less.

Averaging the light cutting with the heavy and making allowance for areas where the grubbing can be omitted, $30 per acre seems a very liberal preliminary price for this item. This is more than double the actual cost at Indian Lake where all stumps were left projecting about two to three feet and the hardwood left to sink, not being thoroly burned.

There is comparatively little pine, hemlock or spruce timber of marketable size within the reservoir. Of the remaining varieties, comprising oak, maple, elm, etc., some of the trees would make good lumber, and the woods could yield a good quantity of piles, poles, ties, fence posts, etc., but it is probable that a large part of the timber would be for convenience turned into cordwood, and that an undue proportion of the tops and large branches would be burned on the ground as being the cheapest method of disposal. Altho the timber would not generally be worth a high price it is likely that with good business management a substantial return could be obtained from the saleable portions, and on some *lots* enough to pay for a large portion of the cost of clearing, and grubbing.

RELOCATION OF HIGHWAYS FOR SACANDAGA RESERVOIR.

A reservoir with the normal flow line at elevation 770 will require the discontinuance of about 67.6 miles of traveled public roads and probably lead to the construction of very nearly 41.0 miles of entirely new roads skirting the shores of the reservoir at a safe elevation above highwater mark; also the raising of the Broadalbin–Mayfield road for a length of 0.9 mile for crossing three arms of the reservoir.

There will be, therefore, a total of 41.9 miles of highway to reconstruct.

The roads replaced by this new construction are quite generally of the ordinary type of country road on which very little work has been done, beyond crowning up the center of the road with sods and earth scraped from the gutters at the sides. In a few instances, some effort has been made to improve short sections of the most important roads by surfacing with gravel or other easily obtainable selected materials, but this latter has been *done only* to a very limited extent.

There are no sections of State road, nor any macadam roads within the limits of the reservoir.

Under these conditions, if the State has to do no more than replace the highways destroyed by others only equally as good, it is probable that the cost of grading, bridging and fencing for the new roads would not exceed $3,000 per mile.

It is likely, however, that the State would be called upon to adopt a more liberal policy and that wherever new State roads are built. around these reservoirs, they will approach to aer gtaer or less degree, according to the importance of the road, the high standards of construction in vogue in the State Highway Department.

This policy of building excellent roads would do much toward settling the margins of the lake with summer cottagers and giving to the valley much more of taxable value and prosperity than it enjoys today.

If this is done, then new roads, with roadways eighteen to twenty-two feet wide, surfaced with gravel or broken stone ten to fourteen feet wide according to traffic requirements and having masonry culverts and substantial bridges, guard fences, etc., cannot be built thru this section for very much less average cost than $6,000 per mile, and this figure is adopted for the purpose of this estimate.

41.9 miles new highways west of center line of Conklingville dam at $6,000 per mile	$251,400
Capitalized value of operation of scow and motor for ferry across reservoir at Northampton, operated about eight months in the year	20,000
Raising and remodeling bridge across Sacandaga river at Northville	4,000
Total	$275,400

RELOCATION OF FONDA, JOHNSTOWN & GLOVERSVILLE R. R.

About six miles of the present location between Mayfield and Cranberry Creek stations will probably be affected by high water conditions in the new reservoir to an extent to require relocation.

But to obtain a favorable new location, it will be necessary to abandon as much as 7.91 miles of the existing line, beginning about 600 feet north of Broadalbin Junction and running to about 4,600 feet north of Cranberry Creek depot.

The proposed relocation as indicated on topography sheets 30, 31, 32, 36 and 37, will be 920 feet shorter than the present location. Therefore, it will require only 7.74 miles of new construction to replace the 7.91 miles to be abandoned.

This means that the new line will be more direct than the present line. Also since the maximum gradient need not exceed 1 per cent. or 52.8 feet to the mile in either direction, and since 4 degree curves are the sharpest it is proposed to use, the new line will compare very favorably with the present line in respect to the rate of ruling grade, curvature and distance. In the matter of rise and fall, however, the proposed location appears to be somewhat at a little disadvantage, but on the whole we believe that the new line when rebuilt according to the proposed specifications, can be easily shown to be more desirable than the line in its present location. The proposed location of depot and station grounds for Mayfield will probably be regarded as more convenient than the present conditions and will give that village improved traffic facilities.

A strip of territory wide enough to include the best location for the new line was carefully surveyed and mapped to a scale of 100 feet to 1 inch. On these maps, a paper location was projected, and preliminary estimates of cost were made in detail for the different classes of construction entering into the work.

A summary of this estimate is presented below.

This estimate provides for a well constructed road, in nearly all respects superior to the one now in use.

The estimate is based on the following assumptions:

Width of roadbed 16 feet on embankments,
18 feet in rock cuts,
20 feet in earth cuts.

All culverts and bridge abutments to be of concrete masonry.

Bridges at highway crossings and streams to be steel spans.

New steel rails, 70 lb. per yard.

Gravel ballast on roadbed. (The present line generally speaking is ballasted only with earth.)

The estimate also provides for right of way 100 feet wide with a liberal allowance of extra width at Cranberry Creek and Mayfield stations; for ample station buildings, sidings, etc., for fencing both sides of track for entire length and for reconstruction of telegraph line.

NOTE.—The total curvature in new line = 129 degrees.
The total rise and fall = 190 feet.

RELOCATION F., J. & G. R. R. FOR SACANDAGA RESERVOIR.

Summary of Detail Estimates of Cost.

		Miles.
Length of new main line		7.74
Length of new side tracks		.76
Total		8.5
95,000 cubic yards earth excavation, at 40 cents		$38,000
133,000 cubic yards borrowed embankment, at 35 cents		46,550
44,000 cubic yards rock excavation, at $1.25		55,000
12 culverts		10,000
6 railroad bridges		38,500
2 highway bridges		7,200
station buildings at Mayfield		5,000
station buildings at Cranberry Creek		2,500
right of way 100 feet wide and station grounds at Mayfield and Cranberry Creek		14,005
8.5 miles main track and sidings at $6,750		57,370
turnouts, frogs, guardrails, etc.		1,000
17 miles right of way fence, at $112		1,900
8½ miles telegraph line, reconstructed		1,000
		$278,025
Engineering and contingencies, 15 per cent		41,700
		$319,725
or about $40,000 per mile.	say	$320,000

GENERAL SUMMARY OF COST—ROUGH PRELIMINARY ESTIMATE.

Reservoir.

29,430 acres of land for reservoir and margins, to flow line elevation 780....	$2,000,000
9,400 acres of clearing and grubbing at $30.....	282,000
Relocation of Fonda, Johnstown and Gloversville Railroad, 8.5 miles complete.	320,000
Relocation of highways, 41.9 miles of new roadways as good as present roads ($2,000 per mile).....	*84,000*
Additional allowance of $4,000 per mile of road to meet probable demands of the public for a higher standard of construction and which might be charged to the State highway appropriation or to local betterments.....	168,000
Capitalized cost of Northampton ferry and remodeling bridge at Northville...	24,000
Rebuilding telephone lines.....	7,000
Conklingville dam, spillway, regulating gates and outlets.....	1,061,000
	$3,946,000
Add for administration, superintendence, engineering, legal expenses and contingencies 15 per cent.....	591,900
Total cost of reservoir and dam for normal flow line elevation 770, as complete and adapted to be used for storage purposes only for benefit of Hudson river below Hadley.....	$4,537,900
or, say, in round numbers.....	*4,550,000*

DETAILS OF ESTIMATES FOR SACANDAGA RESERVOIR.

PRELIMINARY ESTIMATE OF COST OF DAM AT CONKLINGVILLE, N. Y.

At Site "D," indicated on map.

Main portion of dam to be built of earth sluiced into place.

A heavy concrete corewall starting from suitable foundation a few feet below the bed of the river and reaching to 5 feet above the normal flow line, or to elevation 775, extends the full length of the dam. Below the core wall a line of sheet piling driven well down into the bed of very fine sand which fills the ancient channel of the river, has been provided as a cut-off to reduce seepage to a minimum.

The water side of the dam to be protected by a very thick layer of loose rip-rap composed of cobbles and boulders from the earth borrow pits for the dam and from the rock excavation for the over-flow channel. The lower toe of the dam will be amply protected from damage from the back-wash of the flood waters passing through the over-flow channel by building this part of the dam wholly of loose rock to come from the waste way and tunnel excavations The waste way has been designed to be wholly in ledge for the portion around the end of the dam, where any fear of erosion need be felt. The top of the earth dam has been assumed to be 110 feet wide and is considered as carried up to elevation 795 or 25 feet higher than the crest of the spillway.

ESTIMATED QUANTITIES IN MAIN PORTION OF DAM.

1. Earth embankment, 877,000 cubic yards at $0.25..... (25 cents to cover cost of excavation and placing the sluiced earth and the cost of placing rock and earth excavation from the tunnel, waste channel, etc.)	$219,250
2. Excavation of earth and boulders from bed of river for preparation of foundations, 22,000 cubic yards at $1.00..... (This includes core wall trench and cost of pumping.)	22,000
3. Triple-lap sheet piling for cut-off, 6″x50′ long. 700 lineal feet = 350 M. B. M. at $60.....	21,000
4. Concrete core wall, 11,500 cubic yards at $7.00.....	80,500
5. Rip-rap, 27,500 cubic yards at $0.50 for placing.....	13,750
6. Drainage system, 4,000 lineal feet vitrified pipe drains, 8″ to 16″ diam. laid, catch basins, etc.....	4,000
Total for main dam.....	$360,500

Spillway:

7. Earth excavation from spillway channel and entrance channel to same, 135,000 cubic yards at $0.35 (Placing of this is provided for by the 25 cents per cubic yard, item 1.)	$47,250	
8. Rock excavation from spillway channel, 134,600 cubic yards at $1.00	134,600	
9. Concrete lining for floor and rock sides, 16,100 cubic yards at $5.00	80,500	
10. Steel reinforcing rods in floor and sides. 1″ square rods, 12″ spacing east and west. 1″ square rods, 24″ spacing north and south. 450,000 lineal feet, 700 tons at $60	42,000	
11. Cyclopean masonry in rollway, 5,500 cubic yards at $4.50	24,750	
12. Rubble and concrete masonry in retaining walls of wasteway, 18,400 cubic yards at $4.50	82,800	
13. Paving and protection work at junction with river, 500 cubic yards in mortar, $3.00, $1.500; placing rip-rap, etc., say, 2,500	4,000	
Total for spillway		415,900

Intake Works:

14. 800 lineal feet, cut and cover aqueduct, 25′ diameter at $75.50 per foot	$60,400	
15. 500 lineal feet rock tunnel, 25′ diameter, $169.80 per foot	84,900	
16. Gate house, outlet pipes, valves, etc., adapted to use of reservoir for storage purposes only, say (Add another $30,000 for extra cost of gate house, gates, screens, etc., suitable for power project.)	25,000	
17. Sluice gates, weir, etc., at outlet of discharge tunnel	20,000	
Total for intake works		190,300
Grand total		$966,700

Relocation of Highways at Dam:

Additional rock excavation for road north of spillway, 23,000 cubic yards at $1.00	$23,000	
2,500 lineal feet of road on south side, 22′ wide, 14′ macadam at $8,000 per mile	3,800	
1,800 lineal feet of road on north side 22′ wide, 14′ macadam at $4,000 per mile	1,400	
1 140′ concrete span and north abutment for same	6,000	
		34,200
Coffer dams, temporary spillway of timber cribs, rock filled, care of water, etc.		48,000
Dressing slopes, loaming, seeding, etc		12,000
Total estimated cost without any allowance for superintendence, engineering, contingencies, etc		$1,060,900

SACANDAGA POWER PLANT

NECESSARY TO COMPLETE THE DEVELOPMENT IN NEW POWER-HOUSE ONE AND ONE-FOURTH MILES WEST FROM HADLEY, OF ABOUT 75,000 HORSE-POWER MEASURED ON THE TURBINE SHAFT AS FOR REGULAR USE UNDER 40 PER CENT. LOAD FACTOR, WITH OCCASIONAL HIGHER PEAKS.

Generating plant of six equal units of 10,000 kilowatts each equals 60,000 kilowatts, five for regular use, one spare.

Additional cost of intake works to adapt same to power requirements	$30,000	
14,100-foot tunnel, area 315 square feet. (Diameter of equivalent circle, 20 feet.) Average cost per lineal foot, $107	1,510,000	
Bell mouth, fore-bay and gate-house near power-house	88,400	
Regulating reservoir on hill close to power-house	63,200	
Surge pipe and by-pass	14,700	
Six main penstocks and exciter penstock	82,500	
Total for tunnel, head-gates, surge reservoir, emergency gates and penstocks for 80,000 horse power including 15 per cent. for administration and contingencies, about		$2,056,000
or about $25 per horse power.		
Transformer house, excavation, substructure, transformer foundations, etc	$49,000	
Power-house, sheet-piling, foundations, draft tubes, superstructure, crane supports, etc	282,000	
Electrical and hydraulic machinery, six 10,000-kilowatt generators with turbines, governors, exciters, transformers, high and low tension apparatus, switches, copper, etc., complete	998,000	
Auxiliary machinery, gate hoists, oil pumps, water pumps, air compressors, motors, fans, blowers, oil filters, cranes, etc	60,000	
Railroad spurs to power station	18,000	
Lands for tunnel, power station, railroad spur and roads—55 acres.	4,500	
Total for power-house, transformer-house, and all electrical machinery in power-house and transformer-house for 60,000 kilowatt or 80,000 horse power, about		$1,464,000
or about $19 per horse power.		
Total cost of head gates, tunnel and power-house		$3,520,300

Cost per horse power of total machinery, about $44.

DEEPENING SACANDAGA RIVER CHANNEL.

FROM POWER-HOUSE TO HUDSON RIVER.

Borings at various points show that this portion of the river runs over a deep bed of fine sand shingled over with boulders and cobble stones. More borings and test pits are needed, intermediate between those taken, and on both sides of channel before any close estimates of cost of excavating power-house site and river channel can be made. All present data indicate that the covering of loose boulders, which apparently is not more than from two to four feet in average depth, could be picked off by a traveling cableway or cantilever, and piled on the river bed at the side as shown in plates 14 and 16 and that the sand beneath could then be readily dredged and deposited behind the continuous pile of boulders.

It is assumed that the channel would be dredged of regular trapezoidal section, and that the scour of the current would deepen it in the center and undercut the side slopes, making them more flat, and that more or less of the boulders and cobbles would roll down and in time form a tolerably regular rip-rap for protecting the banks of the channel from any serious erosion in time of great floods. Studies of flood conditions and more test pits and surveys are needed for the final design.

The section dredged gives a waterway 15 feet deep and 90 feet in average width or 1,350 square feet, which when not obstructed by ice would carry the mean quantity of 1,900 second feet with a velocity of 1.4 feet per second, or would carry the maximum under 40 per cent. load factor with a velocity of 3.5 feet per second.

The proposed slope is 7 feet fall in 7,900 feet distance or about 4.5 feet drop per mile Therefore the depth would commonly be less than shown on plate 16.

The alignment of this tailrace channel should be composed of straight reaches, as long as possible, and with fewest possible curves and angles. Curves of radius longer than 250 feet should be avoided. If on trial the work is found not expensive, the bottom width might well be 33 per cent. wider than shown, or on the other hand in the first stage and particularly if only one-half the full capacity of power-house be installed at first, only one-half the full width of channel need be built, the boulders being all piled on the north bank.

Although there is at present much uncertainty as to the precise cost at which this channel could be deepened, it promises being well worth the expense. The following estimate of cost is based on $1 per cubic yard, for picking off the boulders from a strip 150 feet in width averaging three feet in depth, and piling them at the side and then dredging a channel 75 feet wide on bottom with one to one slopes in the sand as shown, with sand deposited behind the pile of boulders, at twenty cents per cubic yard. The scour of the current in floods would do some of the excavating.

Dredging 8,200 lineal feet of channel, about	$300,000
Land for dumps	3,000
	$303,000
Add for engineering and contingencies, 10 per cent	30,300
Total estimated cost of tailrace work to utilize full fall to Hudson river	$333,300
The present water level at power-house site is	585.5 feet.
Proposed water level at power-house site	555.5 feet.
Gain in fall	30.0 feet.

Gain in power from 1,700 cubic feet per second at 75 per cent. efficiency on 30 foot fal n 24-hour power on turbine shaft, 4,338 net horse power; in power under 40 per cent. load actor, 10,840 net horse power.

Costing only about $31 per net horse power.

RECAPITULATION SACANDAGA PROJECT.

Dam and reservoir for storage		$4,550,000
Pressure tunnel and power-house and all electric and hydraulic appliances complete	$3,520,300	
Deepening river for tailrace	333,500	
	$3,853,800	
Transmission line to deliver 50,000 kilowatts to Albany and other cities with two independent sets of towers and wires	900,000	
Total cost tunnel, power and transmission		4,753,80
Total cost of complete works for developing gross fall of 222 feet or 80,000 horse power at peaks on Sacandaga river below Conklingville		$9,304,000

As stated on page 147, it is not estimated that the average result in power received by consumers under 40% load factor would exceed 60,500 net horse power in addition to the increase of power from the water thus stored at the present plants along the Hudson.

Thus in round numbers, on a very liberal basis and including interest during construc tion, each of the two stages would cost approximately $5,000,000.

ROUGH ESTIMATE OF COST OF TRANSMISSION LINE FROM SACANDAGA POWER-HOUSE TO ALBANY VIA GLENS FALLS, SARATOGA, WATERFORD, COHOES AND TROY.

(BY R. D. JOHNSON.)

The following rough estimate assumes the transmission of 50,000 kilowatts over a distance sixty-three miles, merely as a convenient first approximation. There is no probability that so large a volume of power would be called for at Albany.

Since the price of copper is now at a minimum and since in reaching other communities, the total length of line might be longer than is here reckoned, and notwithstanding that much less than 50,000 kilowatts would be transmitted so far as Albany, it appears prudent as a first approximation to assume the cost of the transmission line at, say, $900,000. The estimate shows a cost of only $808,000, and is as follows:

To deliver 50,000 kilowatts sixty-three miles, 25 cycles per second, 80,000 volts delivered, power factor 85 per cent.

Put up two lines, each of which would deliver the whole power by crowding it, say, to a 11.1 per cent. loss at peaks.

Lost volts = 10,000.

$$\text{c. m.} = \frac{63 \times 50{,}000 \times 8}{11.1 \times (80)^2} = 355{,}000 \text{ c. m. per conductor.}$$

17,000 pounds per mile — x 63 = 1,070,000 x 18 cents = $193,000.

$$\text{For two lines, c. m. per conductor} = 710{,}000 = \frac{63 \times 50{,}000 \times 8}{X\,\% \times (80)^2} \qquad x = 5.55 \text{ per cent.}$$

The average power paid for would not exceed 35,000 kilowatts on twenty-four-hour basis, so our loss would be only $\frac{35}{50}$ x 5.55 or 3.9 per cent.

Tower line including all labor and material of stringing wire, etc.	$2,100 per mile.
Right of way, 100 ft.-strip, 12 acres per mile	2,500 per mile.
Copper	3,060 per mile.
	$7,660

Cost of two lines (5,160 x 2 + 2,500) x 63 = $808,000, for sixty-three miles.

SACANDAGA PROJECT—YEARLY CHARGES.

FIRST STAGE—USED FOR STORAGE FOR BENEFIT OF HUDSON RIVER POWERS.

The foregoing preliminary estimates have shown for the Sacandaga project in its first stage with dam built and power-house deferred, for all real estate, rights, reservoir, dam, new highways, etc., a cost including interest during construction of about..... $5,000,000

The yearly interest on this, at 4 per cent., is	$200,000
The annual payment to a sinking fund which would at the end of fifty years repay all the cost and leave the State with title clear and all cost recovered, with interest at 4 per cent., would be .655 per cent., or about	33,000
Taxes, or equivalent payment toward support of town government in lieu of taxable property converted, say 1 per cent. on one million dollars	10,000
Maintenance of State highways, built in lieu of present town roads, say	15,000
Depreciation and repair on perishable parts of dam gates and spillway and rip-rap and grassed slopes, say, 3 per cent. on five hundred thousand dollars	15,000

MAINTENANCE.

Nothing is simpler than caring for storage reservoir and occasionally regulating its gates, but altho Indian Lake, for example, would show very low cost of maintenance each year, the State could not hope to carry on this work so cheaply under the higher standards expected of it. We therefore estimate as follows:

For one superintendent, four patrol men and the maintenance of one motor boat and for petty supplies, with occasional work on margins and snags, say per year	10,000
For bookkeeping, power measurement, assessment and collecting of power rentals, say	7,000
Total yearly fixed charges and maintenance	$290,000

The increase in power at sites along the Hudson already more or less developed, shown on page 153, averages about 80,000 horse power of 24 hour power for 6 months in the year. The yearly charges as just figured would therefore, if averaged over *all* of this power, amount to a total cost of $3.75 per horse power per year.

But by no means all of the plants are in position to immediately make use of, or pay for, all of this increased power. A careful canvass would need to be made before any reliable statement of the yearly income could be made.

I have little doubt that investigation would show that some of the largest concerns engaged in the transmission of electric power would receive benefits of upward of $25 per horse power per year and that others engaged in manufacturing would receive the equivalent of at least $10 per year for each horse power under this 100 per cent. load factor.

Therefore it is reasonable to believe that in course of a few years a rental could be secured from, say, two-thirds of the total falls. that would leave the State a large direct profit on the outlay of about $4,500,000 to $5,000,000 for this reservoir *in addition to the large indirect gains* already mentioned.

Merely for purposes of illustration :—

If out of the 80,000 horse power of increased 24 hour power, (remembering that cost of turbines and penstocks and depreciation on same has yet to be provided for by the mill owners) we assume 10,000 horse power, 24 hour power at $25 tax = $250,000 per year.

	10,000	"	"	"	"	"	15	"	150,000 "
	40,000	"	"	"	"	"	10	"	400,000 "
Total taxed	60,000								$800,000

we find a profit above interest and maintenance of over half a million dollars per year. This it should be clearly understood is not presented as an estimate; for the present is merely a progress report, and as stated above, a canvass of the conditions for profitable increase at the several sites has not yet been made.

Altho during this first stage of use for benefit of the water powers on the main Hudson, the storage water would be run for only about six months out of the twelve in an average year, it has substantially the value of an addition of this amount of power for the full year, because this present surplus flow of the flood months is hardly worth putting in turbines for. For example, at Lowell, Mass., and Lawrence, Mass., after more than fifty years of manufacturing activity, the surplus flow of the wet half of the year still runs to waste.

At some of the Hudson plants, the present conditions are different from those at Lowell and Lawrence, since to a moderate extent a surplus of wood pulp can be ground in the months when water is plenty. Nevertheless, as the following table shows, the present turbine capacity in proportion to the flow of the stream is not excessive, and there would be water provided for many additional turbines. The following table shows that at the present time the total turbine capacity at the principal power sites, altho larger than can be filled by the average yield of water in the dryest month, is in general only about half as great as the turbine capacity which could be continuously supplied after the Sacandaga had been regulated as herein proposed.

Any scheme of rentals or taxation for these betterments should provide for a revaluation of the annual rental at intervals of about 20 years, and for rates differing with the use, and lower rates for local use than for long distance transmission.

PRESENT LIMITS OF TURBINE DEVELOPMENT ON HUDSON.

For Twenty-four-hour, Seven-day Flow.

LOCATION.	Mill.	Total catalog horse-power of all turbines now in use.	Approximate feet net fall.	Equivalent total second-feet of turbine discharge.	Approximate present average 24-hour river flow in dryest month of average year including Indian Lake storage. Second-feet.	Proposed regulated flow including delivery from Sacandaga reservoir, second-feet, 24-hour 7-day. (Approx.)	Drainage area. (Approx.) sq. miles.	Present turbine capacity cubic feet per second per square mile. (Approx.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Corinth	Undeveloped	0	20 (?)	0	.....	.....	.....	.....
Palmers Falls	International Paper Co.	22,450	83	1,650	1,600	5,800	2,725	0.90
Spiers Falls	Hudson River Water Power Co., Electric Station	29,500	75	1,650*	1,620	5,800	2,760	1.30
Below Spiers Falls	Undeveloped	0	68 (?)	0	.....	.....	.....	.....
State Dam	State Canal Feeder	(?)	11	(?)	.....	.....	.....	.....
Glens Falls	International Paper Co.	5,157	38	1,500	460	.....	.....	.....
	Finch, Pruyn Co., Paper Mill	10,795	39	.....	970	.....	.....	.....
		15,952	38.7	.....	1,430	5,600	2,785	1.34
Sandy Hill	.....	13,602	67 (?)	1,500	1,440	5,600	2,795	0.66
Ft. Edward	International Paper Co.	6,950	18	1,500	1,440	5,600	2,800	1.25
Crocker's Reef	State Canal Dam	0	5	0	.....	.....	.....	.....
Ft. Miller	Paper Mill	1,289	9	1,500	1,730	5,700	2,950	0.44
Saratoga	State Dam	.....	18	.....	.....	.....	.....	.....
Stillwater	Hudson Valley Traction	580	7	1,800	1,960	6,000	3,680	0.22
Mechanicville	W. Va. Paper Co.	6,586	17.5	2,400	2,440	6,500	4,500	0.76
Mechanicville	H. R. Electric Power Trans. Co.	7,600	18	2,400*	2,440	6,500	4,500	0.85
Troy	.....	.....	7	.....	.....	.....	.....	.....

* Note that the Electric Power Stations use water at a rate that varies from hour to hour, and that the capacity shown above is for peak loads.

1.0 net horse-power under 1.0 ft. fall @ 80% catalog efficiency requires $\frac{550}{62.4 \times 80\%} = 11.0$ second-feet of turbine discharge.

The total fall in vicinity of Corinth and Glens Falls is over 350 feet, and with water-power interests in view, it is obviously better to regulate for uniform flow for this 2,775 square miles of watershed than for the 4,500 square miles at Mechanicville or where the fall is only about 50 feet.

Note— The present extent of turbine capacity is substantially the same as the volume of water flowing in the dryest month in the year. Compare column 6 with column 5.

SACANDAGA POWER-HOUSE OPERATION.

For the second stage of development, the cost of the long tunnel, and of the power-house and its equipment complete and of dredging the tailrace channel and transmission lines, with interest during construction may be as much as..... $5,000,000

Distributing this over the twenty-four-hour seven-day power, if on a 24 hour basis of 30,000 horse power would give a cost of $\frac{5,000,000}{30,000} = \$167$ per net horse power. But this is manifestly unfair because the estimates cover cost of building and equipping with machinery of about 80,000 horse power.

Since the power could probably be ultimately sold under a forty per cent. load factor and to the extent of 60,000 horse power, the cost on this basis $\frac{5,000,000}{60,000} = \$83$ per horse power delivered to consumers, for cost of waterways, station and transmission lines, and exclusive of cost of reservoir.

The cost of steam power for the number of hours per day equivalent to the average number of hours during which this power of 60,000 horse-power could be furnished (which is $\frac{24 \times 7}{6} \times 40$ per cent. = 11.2 hours for 6 days per week), with best modern plant of large size and with cheap coal, would be about $20 per horse power per year, if all fixed charges, insurance, contingencies, depreciation, renewals, etc., are reckoned in.

In the prospectus of the large power plant now under construction on the Connecticut river near Brattleboro, Vt., where 12,000 horse power of twelve-hour power is to be developed, excellent authorities are quoted for the statement that manufacturers in a region fairly comparable with that which this plant would serve, can afford to pay $25 per horse power per year for ten-hour power.

PROBABLE YEARLY COST TO THE STATE FOR FULL SACANDAGA DEVELOPMENT.

(*Rough Preliminary Approximation.*)

OPERATION OF POWER-HOUSE AND TRANSMISSION LINES.

The interest on $5,000,000, at 4 per cent. per year to the State.....	$200,000
Sinking fund fifty years, at 4 per cent. at .00655.....	33,000
Depreciation on perishable parts, $1,250,000, at 4 per cent.....	50,000
Expenditures in lieu of taxes, say.....	10,000
Supplies, oil, petty repairs, insurance, say.....	25,000
Contingencies, accidents, forfeits due failure to supply, say.....	25,000
Attendance, power-house and transmission lines, exclusive of reservoir, say..	75,000
Supervision and bookkeeping, general administration costs, say.....	10,000
Total.....	$428,000

Cost per horse power per year, if all be reckoned as twenty-four-hour seven-day power- $\frac{428,000}{30,000}$ or about $14 per horse power per year, or if reckoned as used on the average 11.2 hours per week day, or under a forty per cent. load factor, the cost per year would be about $6.00, based on complete utilization, which is *only about one-third of the lowest cost of steam power on a ten-hour basis in large plants.*

But one must not be misled by such figures. The full income would not be attained for several years. Much time would be required to secure a line of customers for so large an amount at full prices.

Cities within convenient reach might be supplied at wholesale at $10 to $15 per horse power per year for this 40 per cent. load factor power, which would be equivalent to 0.38 to 0.57 cents per kilowatt hour, and I have little doubt that users for the remainder, at, say, prices ranging from $15 to $25 according to circumstances and subject to increase at end of a five-year, ten-year or twenty-year term, could be found after some years, and that at the suggested revaluations after each ten or twenty years' period, a gradual increase in the scale would be found fair.

THE REAL PROFIT ON THE INVESTMENT.

The chief profit to the State would be largely indirect, and would come from the more complete development of this part of its great natural resources, by which the same drainage area will yield more power and a more uniform power, and through the possibility under State control of devoting this power to more valuable uses and ultimately to purposes that will set many more men at work and build new industrial communities, whereas under private control much of it would be used for replacing steam power now in use.

The gain will come, too, in the creation of lakes more beautiful, by reason of beds and shores better prepared, and with sluices set so high that the lake can never be emptied in severest drought, and by better highways around the new lakes.

From the projected Sacandaga improvement, there would come many benefits which cannot readily be figured in dollars, such as the larger summer flow for diluting the sewage that the river received and for bettering the present source of Poughkeepsie water supply by driving the brackish water farther seaward, the better flow for navigation over the shallows from Troy to New Baltimore, the lessening of the flood depths and dangers at Albany, Troy and at other towns along the stream, and from all these sources the Commonwealth would be benefited, although it merely got a new dollar for an old one in the State Treasurer's bookkeeping.

That there are, however, possibilities of direct return from even the elaborate scale on which this trial design has been laid out, may be seen from the foregoing brief computations presented on pages 173 and 175, which are on rentals assumed at rates that would leave a generous return to the customer.

STUDIES ON GENESEE RIVER.

Inspection at Request of County and City Officials.

Soon after the organization of work under the Fuller bill, the State Water Supply Commission received a request from the county supervisors and later from the Mayor of Rochester, urging a visit of personal inspection by the Commissioners and their engineers and an investigation of the possibilities of power development and flood control on this river. Such a visit was made upon September 13, 1907, the Commission and its engineers being escorted by the Mayor of Rochester, the City Engineer and by delegations from the Board of Aldermen, the City Council and the Rochester Chamber of Commerce.

Proceeding up the valley by the railroad, the large areas subject to disastrous overflow were pointed out, and the several sites for a storage reservoir that had been proposed at Portage and near Mount Morris were carefully inspected. The beautiful scenery of the Genesee Falls and of Glen Iris were also the object

of much attention and comment, and the City Engineer and his assistant, from a crude gaging made at the dams above, estimated that about 100 cubic feet per second was then passing over the falls.

Some of those present called attention to the traditions that beds of quick sand had been found in early days when attempting to tunnel for a railroad through a portion of the rim of the proposed basin and the site of this supposed weakness was carefully noted for future investigation.

The object to which attention was primarily directed by the city officials was that of relief from floods, but investigation of the extent to which the water power of Rochester could be augmented by the release of this stored water was also requested.

Attention was also directed to the reputed suggestion of the late Lord Kevlin, the eminent physicist, on the occasion of his visit to Rochester some years ago, in course of which he is reputed to have suggested that the desired storage and flood control could perhaps best be developed by a series of small reservoirs on the tributaries of the Genesee river, rather than by the construction of a large reservoir either at Portage or Mount Morris.

Although it had at first been considered that the investigations desired on the upper Hudson would consume all the time and all of the appropriation available, it appeared eminently proper that some portion of the time and funds be devoted to the study requested by Rochester, especially so since two widely separated portions of the State would thus each have a local interest in the question of the development of great water powers under State control.

All previous records relating to this matter in the reports of the State Engineer, the State Water Storage Commission, the Rochester Flood Commission, together with the data in the volume published by the Board of Regents concerning the Hydrology of New York and the publications of the U. S. Geological Survey, were searched for data, in order that the smallest possible expenditure in surveys and borings might serve the present purpose.

It is of interest in passing to note that *no specific plan of power development at the Genesee Falls near Portage* was made in the Rafter report of 1896 or in his N. Y. Hydrology. The estimates

of power there presented refer only to the increase at the present power sites within the city of Rochester.

USE OF RESERVOIR FOR FLOOD CONTROL.

Advantages of State Supervision.

On the Genesee river, the construction of a great storage reservoir has been repeatedly urged during the past ten years. The reason which has appealed most strongly to the public is that this would lessen the flood dangers at Rochester and lessen the overflow all along the remarkably level, broad valley through which the river winds for forty miles between Mount Morris and Rochester. It has also been made plain that this reservoir could be made to add largely to the water power of the present factories and power stations at Rochester.

In the final analysis, it now appears that the greatest good to the State at large and to the city of Rochester in particular, from storage reservoir construction, will be found in power development rather than in flood control, for the two purposes are to some extent antagonistic. The full reservoir is best for power. The empty reservoir is best for holding back a flood, but both purposes can be combined to some extent and to do this has been one object of the present study.

The Portage reservoir project is a large one and involves invoking largely the use of the State's right of eminent domain, in the taking of farms and in the moving of homes, although as such matters of reservoir building go, the conditions found above Portage would work no unprecedented hardship. It also involves the changing of the railroad location for several miles along the river and the proposed regulation of the river will change the rate of flow of water over the Genesee Falls, which are the chief feature in one of the State's most beautiful pleasure grounds, a heritage from a distinguished citizen who is a lover of nature and of his fellowmen, and whose wishes are entitled to profound respect.

For these reasons and many others, if this reservoir is to be built, the regulation of the reservoir and the use of the power derived should certainly be retained within the control of the State.

A careful study of the ground and some fairly complete surveys made during the past few months, have caused me to believe that by perhaps changing the location of the dam and by conveying the water for power underground through a deep tunnel to a power house located at least one-half mile or more, probably two miles down stream from the lowest fall, all of this construction could be done without marring the beauty of Glen Iris in the slightest degree. Indeed by means of this storage a greater flow could be provided for the falls at those times when they will be most visited, than is now possible and very much greater than now comes to them under natural conditions in a severe midsummer drought.

By the construction of the proposed Portage reservoir and the development of this very remarkable power site, Rochester and the broad valley above it could be in a large measure, although not entirely, relieved from dangerous floods, and in addition there could be provided the equivalent of 35,000 horse power, twenty-four hours in the day, seven days per week from a new power house to be built a few miles north of Portage.

This amount of power if concentrated largely into ordinary working hours under a forty per cent. load factor, would supply about 60,000 horse power for industrial and municipal uses in the Genesee valley and its neighborhood, exclusive of the mill sites at Rochester and beyond this would add 20,000 horse power to that now furnished by the Genesee within the city limits of Rochester.

Surely when the time comes that the large expenditure involved may be prudently made, the gain to the city and to the State from this reservoir, in flood relief and in new power development, will be far greater than any possible injury.

The power rentals at ordinary prices for steam power would show a good profit, but the marketing of such large amounts of power would be slower under the conditions of to-day, and since the capital involved in the entire development for both dam and power house would be very large, it is to be kept in mind that *the dam could be built and used for flood control and for reinforcing the summer flow of the river at Rochester and adding to the Rochester water powers for a term of years before building*

any power plant at Portage and before building anything connected with the tunnel except its head gates and a hundred feet or so of its upper end.

Much more study is needed for obtaining proper data on many of the important considerations affecting this project, but the main features have been provisionally worked out with a very fair degree of completeness, as will be made plain in the following pages.

STREAM FLOW MEASUREMENTS ON UPPER GENESEE.

The object of first importance in studies of water power, storage and flood control is to learn the volume of flow of the river from day to day.

That portion of the Genesee drainage area lying upstream from the proposed storage dam at Portage is of much greater average altitude than the portion of the drainage area lying down stream from Portage and Mount Morris, and is enough different in character of surface and forest cover, so that it is important to base estimates of yield upon gagings near the site of the storage dam rather than to rely upon the measurements at Rochester, which moreover are understood to lack precision.

The flow of the Genesee, like that of most other rivers, varies so much from month to month that any few scattered gagings however useful for marking the extremes of flood and drought, are without value for estimating power or the requirements of flood control.

Mr. A. S. Kibbe, p. 447, N. Y. State Engineer's Report of 1890, says concerning measurements of the flow of Genesee river prior to his own gagings: "No systematic gaging of its flow has ever been made at one point continuously or for any length of time."

Mr. Kibbe made gagings from June 17th to December 2d, 1890, see p. 716, N. Y. State Eng. Rep. 1896.

The only other continuous gagings of the upper river, of which record can be found prior to 1903, were made at Mount Morris, at the Hydraulic Power Company's dam, where the drainage area is about 1,070 square miles, from September, 1893, to February, 1907, thus covering a period of three years and four months. These were made over a dam with a very irregular crest. (See State Eng. Report 1896, p. 636; also Rafter Hydrology of N. Y., p. 333), which dam was washed away by a flood in February, 1897.

A gaging weir for accurately calibrating the measurements over the old Hydraulic Power Company's dam was built at Mount Morris, 2½ miles upstream therefrom, about August, 1896. (See Rafter Hydrology, N. Y., p. 308, 333, 602.) Unfortunately, it was washed out by a flood about the middle of October, after having been in use only about 2½ months.

Another gaging station on the Genesee also called the Mount Morris station was established by the U. S. Geol. Survey in 1903, and the results have been published without making it plain that this third Mount Morris station was at Jones' Bridge below the mouth of the Canaseraga creek, where the drainage area is about 340 square miles, or 33 per cent. greater than at the old station of the same name. In fact, the State Engineer's reports of 1905, p. 649, gives erroneously for the drainage area of this new station the old area of 1,070 square miles, whereas actually it is about 1,410 square miles.

A fourth gaging station near Mount Morris over the new stone dam called the "High Dam" was established by the U. S. Geol. Survey in 1905.

At Rochester, the Genesee had been somewhat roughly gaged for many years. Mr. Rafter made use of these gagings from February, 1897, to November, 1898, in piecing out his table of flow for the Genesee at Mount Morris. The only records of this series that we find published in the State reports or the United States reports are those from December, 1894, to November, 1896, inclusive, given in the State Engrs. Rept. of 1896, pages 639 and 718–9.

At Elmwood avenue bridge, Rochester, in February 9, 1904, a station was established, as described in State Engineer's report of 1905, p. 650.

In 1903 and 1904, during low water, measurements were made under direction of City Engineer of Rochester at the Johnson and Seymour raceway and on the Carroll and Fitzhugh raceways.

The topographical maps of the U. S. Geol. Survey are as yet incomplete for a large part of the Genesee drainage area. For the drainage area above Rochester, the figure of 2,365 square miles, given in the city engineer's report, has been adopted.

ACCURACY OF MOUNT MORRIS GAGINGS.

Regarding the quality of these gagings, they are not of as high precision as desirable, but doubtless average within, say, five per cent. to ten per cent. of the exact figure, and from a study of description of the form of crest used in September, 1906, to calibrate the Hydraulic Power Company's dam, the actual flow is, say, probably five per cent. greater than the computed flow.

Opposite page 602 of Hydrology of N. Y. are shown photographs of the timber dam and of the measuring weir and on p. 308, Hydrology, is shown the cross section of the measuring weir.

I find no good reason for the adoption by Mr. Rafter (see p. 718, State Engrs. Rept. 1896) of the Francis formula $Q=3.33\ LH^{\frac{3}{2}}$ for computing the flow over this standard weir, which had a queer form of crest, very different from that prescribed by Mr. Francis, giving less contraction at the underside of the jet, and which form would therefore give a somewhat larger discharge than the standard Francis weir.

The comparisons of discharge between this calibrated weir and the dam crest presented on p. 334 of the Hydrology, lack satisfactory agreement, but while more precise gagings covering a much longer term are desirable, we have here already measurements of actual flow longer and more accurate than those on which the preliminary plans of the great majority of water power installations have had to be based, and since these Rafter gagings probably slightly underestimate the flow and embrace the remarkably severe drought of 1895, they are on the safe side.

In addition to the period from September, 1893, to November, 1897, covered by the actual gagings at Mount Morris, Mr. Rafter in Hydrology of N. Y., p. 333, estimated the probable flow at the storage site from April, 1890 to November, 1892, from some actual gagings that had happened to be maintained during that period for other purposes on Oatka creek, a lower tributary, of only about one-fortieth of the area above Portage, which probably, because of

its lower altitude and its lack of forest and its smaller area, has a less prolific yield than the Genesee at Portage, thus again making the error on the safe side.

From December, 1892 to August, 1893, in the absence of gagings, he deduced the run-off from the rainfall, and subsequent to the loss of the dam from November, 1897 to November, 1898, inclusive, the flow from Mount Morris was deduced from the record at Rochester, which from embracing much drainage having lower altitude and smaller rainfall than the portion above Portage, again tends to bring the estimate of the discharge of the river at Portage on the safe side.

In the nine years of probable monthly flow, thus deduced, it is of great interest to note that the year of smallest run-off, 1895, and the year of largest run-off, 1894, fall within the period covered by the daily gagings at Mount Morris, wherefore these records of daily fluctuations during this period may prudently be used as a safe guide in computing the storage requirement and the power yield for the proposed site. We will later examine the rainfall records from 1825 to 1907 for possible warning against any period more severe.

STORAGE REQUIREMENTS AT PORTAGE.

The best method of computing the storage requirements for a given drainage area from records of stream flow is by the mass curve method. (See plate 18.)*

Plotting this mass curve from the nine years run-off data just described, it immediately is plain that the most severe period in providing uniform delivery of water for power, or in other words, the series of years of smallest yield, is from July 1, 1894 to June 1, 1898.

Starting with reservoirs full after the heavy rainfalls of March, April and May, 1894, a uniform discharge at the rate of 800 cubic feet per second from the entire drainage area of 950 square miles, could have been steadily maintained throughout every day of this extreme drought. This is equivalent to a total run-off of 11.4 inches per year in depth from the tributary watershed.

The divergence of the mass curve from the draft line shows that maximum reservoir depletion at the end of the drought would have been equivalent to 5.0 inches depth on entire drainage area of 950 square miles, which in other words is 11,700,000 cubic feet.

The proposed reservoir above Portage according to table on p. 708–9, N. Y. State Engineer's report of 1896, would contain this quantity with water at elevation of 1,190 feet above sea level and is therefore of ample size to store some of the surplus of the year of heavy rainfall and to carry the surplus over for the year of drought and *with dam built of the height that I propose would have* 20 *feet in depth of reservoir at its top where content per foot of depth is greatest, always available for flood control.*

In the year 1895, according to the concurrent testimony of all the rainfall records of the region around the watershed of the Genesee above Portage (viz. at Humphrey, Arcade, Angelica, South Canisteo and Alfred) the rain-

* NOTE.— The 800 second feet draft line on plate 18 is too large, but due to the weight of other considerations it is thought best to let it stand.

fall was only about 75 per cent. of the normal and moreover was less than in any other one of the twenty-nine years since the rain gage of the Rochester water works was established at Hemlock lake.

The average run-off for the whole nine-year period as deduced from the incomplete gagings already described was 14.2 inches per year equivalent to a flow from 1,000 square miles of $\frac{14.2 \text{ inches}}{12 \text{ months}}$ x 0.884 factor x 950 sq. m. = 994 or say 1,000 cu. ft. per sec.

The lack of precision in river gagings at Mount Morris appears to be all on the side of underestimating the flow, and the most probable value for *yield in severest drought* is 850 to 900 cubic feet per second.

A flow averaging 1,000 cubic feet per second (equivalent to 1.13 inches run-off per month from the watershed of 950 square miles) could be delivered in many years without nearly emptying the reservoir, but a yield of 800 cubic feet per second can apparently be depended upon in what may be classed as the dryest year of the half century.

In such an exceptionally dry year as 1895, or once in a lifetime, some curtailment of the power could be provided for, and some reduction in the number of hours, or the volume of water poured over the falls for scenic effect could be conceded, and I consider that the data in hand amply justifies the opinion that after making a fair provision for preserving the beauty of the cascades, and with the proposed reservoir flow line at say, elevation 1,210, there can be delivered from the Portage reservoir for power purposes, twenty-four hours per day, seven days in the week, throughout every year but the most extreme, 750 cubic feet per second.

PROPOSED PORTAGE RESERVOIR.

The maximum depletion caused by maintaining a constant draft of 800 cubic feet per second, partly for power, partly for scenic effect, would have been as shown in table below.

YEAR.	Maximum depletion. Inches on drainage area.	Date of low point.	Total cubic feet depletion from full capacity.	Cubic feet capacity left in reservoir of 15 billion cubic feet total capacity.	Elevation of water at lowest point of the year. Feet above sea level.
1890....	1	Sept. 1.....	2,300,000	12.7	1,193
1891....	3	Dec. 1.....	7,000,000	8.0	1,175
1892....	1.2	Dec. 1.....	2,800,000	12.2	1,191
1893....	2.7	Dec. 1.....	6,300,000	8.7	1,178
1894....	2.0	Dec. 31.....	.....	.....	.....
1895....	2.5	Feb. 28.....	5,800,000	9.2	1,180
1895....	5	Dec. 1.....	11,700,000	3.3	1,148
1896....	2.6	Oct. 1.....	6,000,000	9.0	1,180
1897....	2.5	Nov. 1.....	5,800,000	9.2	1,181
1898....	1.6	Oct. 1.....	3,700,000	4.3	1,188

STUDY OF MORE ANCIENT RAINFALL RECORDS.

The period of actual gagings of the river flow at Portage having been so brief, it becomes important to learn how the rainfall in these years compared in quantity precipitated with the normal rainfall of the locality, and it is also important to confirm the accuracy of these river flow gagings by comparison of the yield per square mile on this watershed with that found on other watersheds, making due allowance for differences in rainfall.

A search for all reliable rainfall records in this region for a long term of years, finds only the following. These have been grouped according to nearness to upper or to lower watershed and according to elevation.

SOUTHERLY OR PLATEAU GROUP. REPRESENTATIVE OF DRAINAGE AREA ABOVE PORTAGE.

STATION.	Elevation.	Mean rainfall.	Records from — to —.
Angelica	1,340	41.36	1889–1890; 1892–1898; 1900–02; '06
Alfred	1,795	38.24	1890–1898; 1900.
Humphrey	1,950	45.82	1889–1897; 1901.
South Canisteo	1,480	41.21	1890–1906.
Arcade	1,570	41.74	1891–1898; 1904–1905.
Average	.....	41.67	

NORTHERLY OR LOWLAND GROUP. REPRESENTATIVE OF DRAINAGE AREA OF LOWER RIVER.

STATION.	Elevation.	Mean rainfall.	Records from — to —.
Rochester	523	33.67	For 70 years since 1830.
Hemlock Lake	900	28.47	1878–1895; 1898; 1902–1906.
Ithaca	836	33.14	For 42 years since 1829.
Geneva	507	31.22	1855–1862; 1864–1867; 1883–1892.
Wyoming	965	30.61	1826–1848.
Average	.....	31.42	

It will be noted in comparing the above, that the rainfall in the plateau region tributary to the Genesee above Portage is distinctly larger than for the lower river; giving the stations equal weight, the average excess is 10.25 inches, and we may therefore expect the yield per square mile for the portion above Portage to be distinctly larger than for the entire area tributary above Rochester.

This is discussed more fully with the aid of compensated rainfalls and isohyetal lines upon a later page. (See page 188 below.)

All of these annual rainfalls have been plotted year by year on two diagrams, plate 17. On the first the ordinates are proportional to the actual precipitation; on the second the ordinates give the percentage which the

precipitation in each particular year bears to the normal or long term average for that particular locality.

The second diagram gives the most convenient comparison, and it is of particular interest to note how concurrent these records are, showing that the conditions are widespread and the precipitation substantially uniform over the watershed in question, and that a dry year in one part of this drainage is a dry year over it all.

This fact enables us to accept with more confidence the record of the fewer stations of the earlier years as representative of the whole territory now under consideration.

From these diagrams we confirm the conclusion already stated, that the year 1895 presented conditions of small rainfall and therefore of small run-off, severe as any that have occurred within the past half century.

From these diagrams we have sought to compensate the averages of short term rainfall observations so as to correct for the period in which they were taken having happened to be extra wet or extra dry, and the first step for this is the determining of the ratio of the precipitation to normal in any particular year. The method of compensation will be plain from the following table.

RECORDS OF RAINFALL AT STATIONS IN OR NEAR THE DRAINAGE AREA OF THE GENESEE RIVER.

COMPENSATED FOR SHORT TERM VARIATIONS.

RAINFALL STATION.	Elevation.	Annual mean inches.	Years.	Duration of record.	Probable ratio of rainfall in this period to the long term mean.	Compensated annual mean for this station.
	Feet.			Dates from—to—inclusive.	Per cent.	Inches.
Addison	1,000	33.12	16	1891–1906	100	33.1
Alfred	1,795	38.24	10	1890–1898, 1900	100	38.2
Angelica	1,340	41.36	13	1889–1890, 1892–1898, 1900–1902, 1906	100	41.4
Arcade	1,570	41.74	10	1891–1898, 1904–1905	100	41.7
Atlanta	1,200	35.79	8	1891, 1893–1894, 1897–1899, 1905–1906	94	38.1
Avon	585	29.06	11	1891–1892, 1897, 1899–1906	101	28.8
Canandaigua	790	37.03	10	1829–1838	93	39.8
Charlotte	273	29.13	9	1860–1867, 1871	102	28.5
Friendship	1,536	39.32	4	1893–1896	92	42.7
Geneva	507	31.22	22	1855–1862, 1864–1867, 1883–1892	.....	31.2
Haskinville	.....	32.70	10	1896–1905	97	33.7
Hemlock Lake	900	28.47	23	1878–1895, 1898, 1902–1906	.....	28.5
Henrietta	600	26.80	2	1835–1836	84	31.9
Humphrey	1,950	45.82	10	1889–1897, 1901	.....	45.8
Le Roy	888	40.14	6	1892–1894, 1904–1906	101	39.6
Little Genesee	.....	37.74	7	1867–1873	100	37.7
Lyons	426	34.67	13	1890–1895, 1897–1900, 1902, 1904–1905	101	34.3
Mt. Morris	525	25.44	2	1896–1897	100	25.4
Ovid	800	38.50	2	1856–1857	111	34.7
Prattsburg	1,494	32.94	9	1829–1830, 1839–1845	100	32.9
Rochester	523	33.67	70	1830, 1834–1850, 1852–1866, 1868–1869, 1871–1882, 1884–1906	.....	33.7
Romulus	719	33.57	8	1892–1899	105	32.0
Rose	.....	37.03	3	1896–1898	102	36.4
Seneca Falls	463	36.22	1	1852	98	36.9

Shortsville	740	31.07	6	1900–1905	101	30.8
South Canisteo	1,480	41.21	17	1890–1906	.....	41.2
Starkey	.....	36.81	4	1875, 1877–1879	103	35.7
Varysburg	.....	36.77	2	1894–1895	98	37.6
Wyoming	965	30.61	17	1826–1848	.....	30.6

From the average rainfall at the many different stations as obtained in the foregoing table an isohyetal map has been prepared, a reduced copy of which is presented in plate 19.

The lines of equal precipitation are not so regular or so completely defined as we might like, but they prove most clearly the large excess of rainfall over the watershed above Portage in comparison with that on the lower Genesee.

These curves show the mean annual precipitation on the drainage area above Portage is 38 inches, while for the entire Genesee drainage above Rochester it is about 34 inches; and it would have been of some interest to compensate and increase that part of our mass curve that was based on Rochester gagings at least 13 per cent. so as to allow for that, and also to increase the portion derived from the Oatka Creek gagings, where normal rainfall is apparently about 33 inches, by 15 per cent.; but it has hardly seemed worth while to retrace these curves, particularly as they are on the safe side. The rate of increase in run-off would doubtless be larger than the percentage of increase in rainfall just noted.

Comparing the yield of the Genesee watershed with that from the upper Hudson watershed, we find the rainfall and run-off for the Genesee are much smaller; indeed the probable run-off year by year from the Genesee above Portage is just about one-half as great as that from the Sacandaga, notwithstanding the drainage areas happen to be substantially equal.

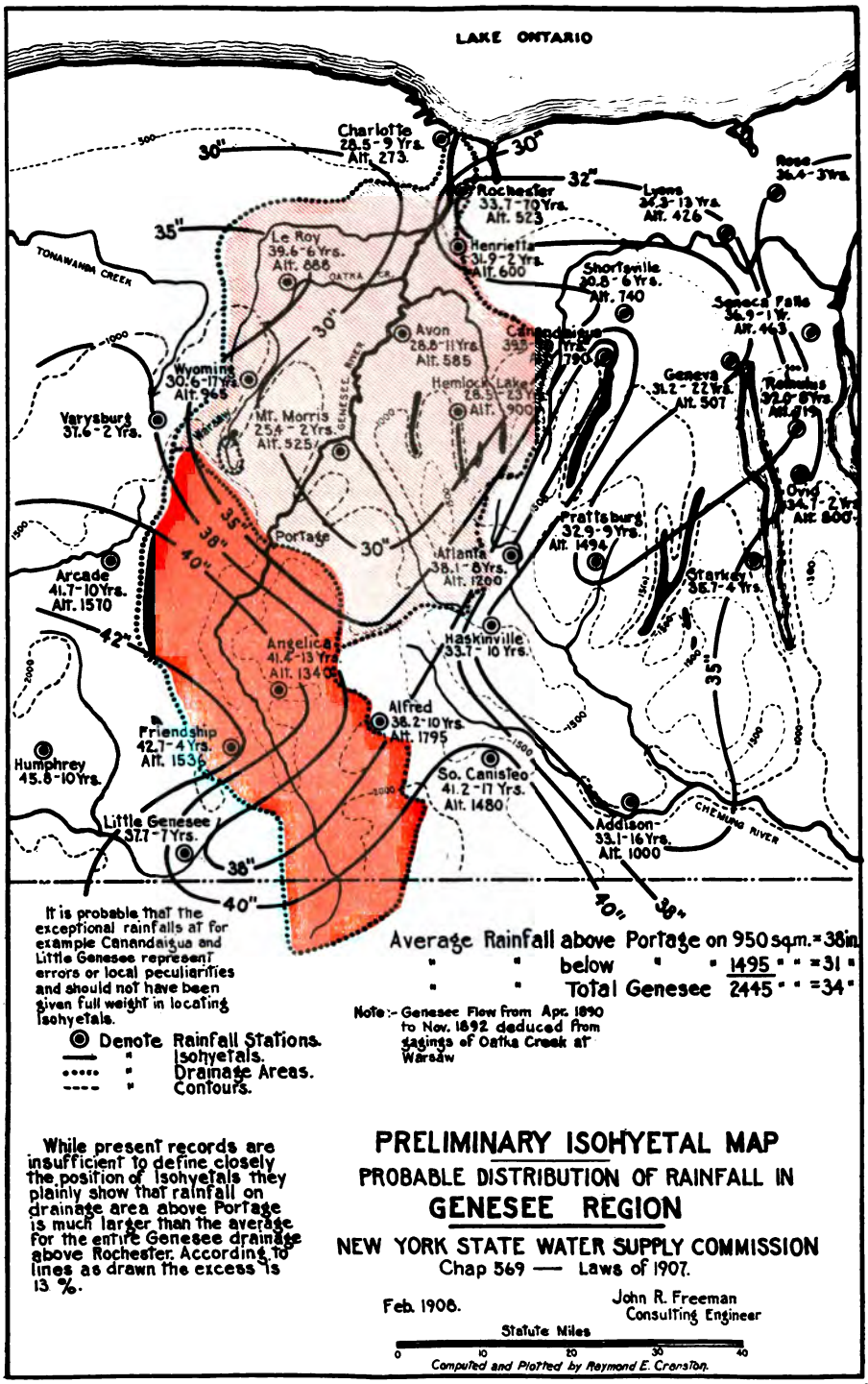
On the Sacandaga we have abundant forest cover and on the Genesee there appears to be a remarkably small amount; at least this is the case in the vicinity of the reservoir. No special tour of reconnaissance thrrough the extreme upper Genesee watershed for the purpose of judging of its quality has yet been made by a member of our staff other than that for studying the sites for small reservoirs, but so far as examined the drainage area was found nearly deforested.

QUANTITY OF WATER TO BE RESERVED FOR SCENIC EFFECT IN GLEN IRIS.

I have been very desirous of obtaining a series of observations at different stages of the river, each set consisting of an accurate measurement of the quantity of water flowing, combined with good instantaneous photographs showing the appearance of each of the three cascades with precisely this quantity of water passing, but conditions thus far have not been favorable.

These observations would tell better than any written description just what flow was reasonably necessary to be maintained for scenic effect. It was estimated by engineers of the City Engineer's office at Rochester from depth measured in the Portageville dam, that on the occasion of the visit of the Mayor and other city officials and of the State Water Supply Commission upon September 13, 1907, the flow was at the rate of about 100 cubic feet per second, but the conditions for a precise measurement at that time were not good. It is certain that the falls at that time presented a scene of great beauty and that the volume of water was not large.

During the period covered by Mr. Rafter's gagings in 1893 and 1896, the summer flow was for long periods only about 100 cubic feet per second, and during the season when this beautiful spot will be most frequented by those



It is probable that the exceptional rainfalls at for example Canandaigua and Little Genesee represent errors or local peculiarities and should not have been given full weight in locating Isohyetals.

◎ Denote Rainfall Stations.
——— " Isohyetals.
••••• " Drainage Areas.
---- " Contours.

Average Rainfall above Portage on 950 sq.m. = 38in.
" " below " " 1495 " " = 31 "
" " Total Genesee 2445 " " = 34 "

Note:- Genesee Flow from Apr. 1890 to Nov. 1892 deduced from gagings of Oatka Creek at Warsaw

While present records are insufficient to define closely the position of Isohyetals they plainly show that rainfall on drainage area above Portage is much larger than the average for the entire Genesee drainage above Rochester. According to lines as drawn the excess is 13 %.

PRELIMINARY ISOHYETAL MAP

PROBABLE DISTRIBUTION OF RAINFALL IN GENESEE REGION

NEW YORK STATE WATER SUPPLY COMMISSION
Chap 569 — Laws of 1907.

Feb. 1908.

John R. Freeman
Consulting Engineer

Statute Miles
0 10 20 30 40

Computed and Plotted by Raymond E. Cranston.

PLATE 19

appreciative of the beauties of nature, the flow under natural conditions would probably commonly be somewhere between 100 and 200 cubic feet per second.

At present and subject to revision on further study, it appears to me reasonable to reserve, secure against all encroachment, a flow during the daylight hours from June 1st to November 1st, of not less than 100 cubic feet per second, and to provide for a larger flow on special occasions and holidays. In all years of ordinary rainfall, it would be entirely feasible to provide for the larger flows on many days without serious detriment to the water power. Sluice gates are proposed of a type easily and quickly operated, and in case the upper ten feet or fifteen feet of reservoir capacity is reserved for flood relief, this water could be discharged over the falls in daylight hours.

A reserve of water for scenic effect could be made secure by placing the feeder gates of the water power tunnel at such an elevation that below this level there would be left water enough for, say, 100 days' supply at 100 cubic fet per second, daily, from sunrise until 10 P. M.

The quantity to be discharged would always be under easy control by the sluice gates in the base of the dam, and since in these studies State ownership and control of the dam and power tunnel is proposed, the people would through their representatives always have in their control the precise limit at which from time to time to draw the line between the quantity that could properly be used for power and the quantity that should properly be reserved for scenic purposes.

Although the time is likely to come within a half century or less, when it will be deemed as wrong to be unduly extravagant of the great sources of power in nature as to start a conflagration for its sublime spectacle, there will still be some generous proportion of this water which can serve its highest possible use in administering to pleasure of mankind by giving its share in the rare beauty of Glen Iris.

For present purposes and subject to revision, I therefore compute the water available for power, as what is left after in the average year providing for a flow over the falls of not less than 200 cubic feet per second from June 1st to November 1st, from sunrise to 10 P. M., shutting the flow off more or less at night, and in years of smallest rainfall as much as now flows, or not less than 100 cubic feet per second from June 1st to November 1st, and at other seasons of the ordinary year, not less than 100 feet by day, shutting this cold season flow off more or less at night, or in years of severe drought.

Even after the power development begins, many years would elapse before full use to best advantage would be found for the vast quantity of power the Portage works would furnish, and the surplus water stored could be used during all these years to give the falls a much greater volume of summer flow than they at present possess.

If the dam should be built first mainly as a flood storage proposition and the local tunnel and power house deferred for some years, the storage could be regulated and discharged at hours selected mainly with regard to the scenic effect.

Whatever was released for scenic purposes at Portage would, of course, serve its full use for power at Mt. Morris and Rochester.

In the following table an estimate is made of additional water power that could be made available through the construction and use of this storage reservoir.

In the first computation it is supposed used solely for flood control and for the benefit of the power at Rochester and Mt. Morris while the Portage power plant is deferred.

In the second computation the effect in increased power at Rochester is estimated on the supposition that a Portage power house is built and uses all water except that reserved for scenic purposes at substantially a uniform rate throughout the year.

AVERAGE MONTHLY RUN-OFF (IN INCHES ON DRAINAGE AREA) OF THE GENESEE RIVER, FOR THE YEARS 1890–1898, INCLUSIVE, ALSO 1904 AND 1905.

(From the published gagings previously described.)

MONTH IN ORDER OF DRYNESS.	Month that will probably most often stand in this order.	1890.		1891.		1892.		1893.		1894.		1895.	
		Inches run-off.		Inches run-off.		Inches run-off.		Inches run-off.		Inches run-off.		Inches run-off.	
1	September	Aug.,	0.28	Oct.,	0.24	Sept.,	0.24	July,	0.30	July,	0.14	Sept.,	0.10
2	August	July,	.38	Aug.,	0.25	Oct.,	0.33	Sept.,	0.33	Aug.,	0.22	July,	0.11
3	July	Dec.,	1.00	July,	0.37	Nov.,	0.57	June,	0.34	Oct.,	0.44	Oct.,	0.11
4	October	Sept.,	1.35	Nov.	0.41	Jan.,	0.78	Aug.,	0.35	Nov.,	0.82	Aug.,	0.12
5	June	Jan.,	1.70	June,	0.44	Dec.,	1.04	Oct.,	0.38	Feb.,	0.86	June,	0.13
6	November	June,	1.85	Sept.,	0.46	June,	1.41	Nov.,	0.54	Sept.,	0.93	May,	0.19
7	December	Nov.,	2.13	May,	0.63	Aug.,	1.43	Feb.,	1.29	June,	1.10	Feb.,	0.22
8	January	April,	2.17	Dec.,	0.97	Feb.,	1.66	Dec.,	1.45	Jan.,	1.40	Nov.,	0.47
9	February	Oct.,	2.27	April,	1.39	May,	1.75	Jan.,	1.96	Dec.,	2.34	Dec.,	0.61
10	May	Mar.,	2.40	Jan.,	2.62	Mar.,	1.94	Mar.,	2.31	Mar.,	3.31	Jan.,	0.66
11	April	Feb.,	2.53	Mar.,	2.87	July,	2.06	April,	2.51	April,	3.39	Mar.,	1.94
12	March	May,	3.16	Feb.,	3.40	April,	2.21	May,	2.61	May,	4.43	April,	2.01

AVERAGE MONTHLY RUN-OFF (IN INCHES) OF THE GENESEE RIVER—(*Continued*).

MONTH IN ORDER OF DRYNESS.	1896.	1897.	1898.	1904.	1905.	TOTAL.	AV. 11 YRS.
	Inches run-off.	Inches run-off.	Inches run-off.	Inches run-off.	Inches run-off.	Inches run-off.	Inches run-off.
1	Sept., 0.16	Sept., 0.18	July, 0.45	Sept., 0.21	Sept., 0.25	2.55	0.232
2	May, 0.17	Oct., 0.18	Sept., 0.50	Nov., 0.24	Oct., 0.29	3.00	0.273
3	Aug., 0.20	Nov., 0.37	Oct., 0.78	Aug., 0.26	June, 0.31	4.75	0.432
4	July, 0.24	Aug., 0.44	Aug., 0.80	Dec., 0.54	Aug., 0.48	6.33	0.575
5	June, 0.39	June, 0.44	June, 0.80	Oct., 0.58	May, 0.49	7.25	0.659
5	Jan., 0.47	July, 0.46	Dec., 0.95	July, 0.60	Feb., 0.51	8.37	0.761
7	Nov., 0.82	Jan., 0.78	May, 1.25	June, 0.97	Nov., 0.62	11.24	1.022
8	Feb., 0.91	Feb., 0.79	Nov., 1.40	May, 1.66	July, 0.68	13.56	1.233
8	Dec., 1.32	Dec., 0.79	April, 1.65	Feb., 2.51	Jan., 1.32	17.91	1.628
10	Oct., 1.74	May, 0.99	Feb., 1.85	Jan., 2.63	Dec., 1.58	21.03	1.912
11	Mar., 3.00	April, 1.31	Jan., 1.95	April, 3.72	April, 2.10	27.38	2.489
12	April, 3.38	Mar., 2.65	Mar., 2.75	Mar., 8.44	Mar., 3.64	38.68	3.516
							14.732

GENESEE STORAGE (FIRST STAGE).

Increased power at present Genesee River Plants if Portage Reservoir be used solely for storage, and so regulated as to produce the most uniform rate of flow at Rochester.

800 cubic feet per second for entire year = 11.44 inches depth on watershed of 950 sq. miles.

In this "First Stage" the discharge is supposed regulated wholly with a view to uniform flow and maximum power at Rochester—as might be done until proposed Portage power station is built.

In the "Second Stage" the discharge of storage is supposed so regulated as to give best efficiency for a power station just below Portage—this calling for substantially a uniform flow at Portage.

MONTH IN ORDER OF DRYNESS.	Name of month oftenest in this order.	Average yield per sq. m. of watershed, inches.	Natural flow all except Portage, 1,415 sq. m. (above Roch.) c. f. s.	C. f. s. drawn from storage, Portage.	Equiv. inches drawn from storage.	Total regulated flow at Rochester. c. f. s.	Natural flow at Portage, 950 sq. m. c. f. s.	Increased flow due to storage. c. f. s.	24-hour 7-day horse power from increased flow on 1 ft. fall, at 75% efficiency.
1	September	0.232	290	1,610	1.92	1,900	195	1,415	120.40
2	August	0.273	341	1,559	1.86	1,900	229	1,330	113.18
3	July	0.432	540	1,360	1.62	1,900	363	997	84.84
4	October	0.575	719	1,181	1.41	1,900	483	698	59.39
5	June	0.659	824	1,076	1.28	1,900	553	523	44.50
6	November	0.761	951	949	1.13	1,900	639	310	26.38
								+5,273 E	6)448.69
7	December	1.022	1,278	622	.74	1,900	858	—236	74.782
8	January	1.233	1,541	359	.43	1,900	1,035	—676	
9	February	1.628	2,035	200	.24	2,235	1,366	—1,166	
10	May	1.912	2,390	200	.24	2,590	1,604	—1,404	
11	April	2.489	3,112	200	.24	3,312	2,089	—1,889	
12	March	3.516	4,396	200	.24	4,596	2,951	—2,751	
		14.732			11.35		1,030*	—8,122*F	

*The yield at Portage in an average year will be 1,030 c. f. s., against the mean dry year flow of 800 c. f. s. that could be drawn through sluices at a uniform rate— or whose equivalent is drawn at a rate varying from day to day as needed to supplement lower river. This leads to F being numerically larger than E.

Note that whereas Mr. Rafter's report of 1896 proposed a uniform regulated flow at Rochester of 1,080 c. f. s. the above computation shows that with this reservoir it will be possible to give in an ordinary year 1,900 c. f. s. at Rochester, or 80 per cent. more.

GENESEE STORAGE (FIRST STAGE).

Increased power at present Genesee River Plants if Portage Reservoir be used solely for storage.

	Working head.	Added in dryest month.	2d	3d	4th	5th	6th
Mt. Morris	18	2,167	2,037	1,527	1,069	801	475
Geneseo (approx.)	6	722	678	509	356	267	158
York (approx.)	5	602	565	424	296	222	132
Rochester	.....	.....	.....	.....	.....	.....	.....
Johnson and Seymour Dam	19	2,288	2,150	1,613	1,128	845	500
Upper Falls	92	11,078	10,412	7,805	5,464	4,094	2,427
Middle Falls	28	3,372	3,169	2,375	1,663	1,246	739
Lower Falls	96	11,559	10,865	8,144	5,701	4,272	2,533
	264	31,788	29,876	22,397	15,677	11,747	6,964

Total 118,449
Average 19,738

Average 6 mo. = 264x74.782 = 19,738.

The storage adds an average net 24-hour 7-day power of 19,738 h. p. for dryest 6 months, providing each of the above heads or falls is fully used.

The above if used mostly in ordinary working hours or under a 40 % load factor would amount to nearly 50,000 horse power.

Above is based on (min. flow in average year at Rochester of 1,900 c. f. s.), or 11.35 inches stored and released at Portage.

(800 c. f. s. for entire year is equivalent 11.44" on watershed 950 sq. miles.)

GENESEE RIVER STORAGE (SECOND STAGE), PORTAGE RESERVOIR.

Increased power at present Genesee River Plants if constant flow of 700+100=800 c. f. s. be drawn from Portage Reservoir. Drainage area at Portage=950 sq. miles. 1-inch run-off per month from 950 sq. miles

$$= \frac{950 \times 5280 \times 5280 \times .0833}{30.44 \times 24 \times 3600} = 839.2 \text{ cu. ft. per sec.}$$

Number of month in order of dryness.	Probable name of month.	Average yield per square mile of watershed in inches.	Average natural yield at Portage c. f. s. 950 square miles. ×839.2.	Regulated yield (700+100) c. f. s.	Increased flow in river below due to regulation.	24-hour 7-day horse power of increased flow on 1 foot fall at 75% eff ×.0851.
1	Sept.	0.232	195	800	605	51.48
2	Aug.	0.273	229	800	571	48.58
3	July	0.432	363	800	437	37.18
4	Oct.	0.575	483	800	317	26.97
5	June	0.659	553	800	247	21.02
6	Nov.	0.761	639	800	161	13.70
					2,338	6 | 198.93
7	Dec.	1.022	858	800	—58	*33.15
8	Jan.	1.233	1,035	800	—235	
9	Feb.	1.628	1,366	800	—566	
10	May	1.912	1,604	800	—804	
11	April	2.489	2,089	800	—1,289	
12	March	3.516	2,951	800	—2,151	
		14.732	Av. 1,030		—5,103	

*Average for six months.

GENESEE RIVER STORAGE (SECOND STAGE) PORTAGE RESERVOIR.

Increased power on present Genesee River Plants if constant flow of 700+100=800 c. f. s. be drawn from Portage Reservoir.

	Working head.	Added in dryest month.	2d	3d	4th	5th	6th
Mt. Morris	18	927	874	669	485	378	247
Geneseo (approx.)	6	309	291	223	162	126	82
York (approx.)	5	257	243	186	135	105	68
Rochester	.....	.....	.....	.....	.....	.....	.....
Johnson and Seymour Dam	19	978	923	706	512	399	260
Upper Falls	92	4,736	4,469	3,421	2,482	1,934	1,260
Middle Falls	28	1,441	1,360	1,041	755	589	384
Lower Falls	96	4,942	4,664	3,569	2,589	2,018	1,315
	264	13,590	12,824	9,815	7,120	5,549	3,616

Total 52,514 Average 33.155 x264=8,752.

Or the storage adds an average net 24-hour, 7-day horse power for six dryest months of 8,752 H. P., if each of above falls be fully utilized. If concentrated in ordinary working hours, or under a 40 % load factor, this would amount to about 22,000 horse power added to the present resources of the stream over and above what is added at the new power site

FLOOD CONTROL BY GENESEE STORAGE RESERVOIR.

The chief purpose urged heretofore in proposing the construction of great storage reservoirs on the Genesee, first near Mt. Morris and later at the Portage site, has been the protection of the city of Rochester and the broad flat valley of the river lying between Mt. Morris and Rochester from the severe floods, which from time to time have inundated and endangered a large portion of the city, but in the report presented by Mr. Rafter, in the Report of the State Engineer for 1896 and as subsequently presented in the volume on the Hydrology of New York in 1905 and in sundry other publications, great stress has also been laid upon the increase of water power at sites within the city of Rochester, already developed and owned by private corporations, that would also result from the use of these reservoirs.

The great floods from which Rochester has suffered most severely occurred on the dates named below on pages 196 and 197. The feature now of special interest is that these floods have occurred in spring, summer and autumn, in every month except August. So far as I can learn the estimates of cubic feet per second flowing given on this page and the next are very rough.

Data From Report of Rochester Flood Commission of 1905.

1902, July 5th to 9th. From a heavy rainfall on ground saturated by previous heavy rains. Precipitation July 6th at Angelica 4.5 inches. Flood above Portage "heaviest ever known." Maximum rate of flow at Mt. Morris probably 40,000 cubic feet per second. Maximum rate of flow at Rochester only about 20,000 cubic feet per second. Great loss of growing crops in Genesee Valley due to flooding over flats.

1902, March 3rd. Mainly from melting snow. Total rainfall in 3 days previous about 1 inch. Less than maximum rate of flow at Rochester, about

38,000 to 40,000 cubic feet per second. Some cellars flooded and considerable overflow in various parts of city.

1896, April 4th. Maximum rate of flow at Rochester 35,000 to 36,000 cubic feet per second. Some cellars in Rochester flooded. Flats in valley from Rochester to above Mt. Morris covered.

1894, May 20th to 23rd. Maximum rate of flow at Mt. Morris 42,000 cubic feet per second. Maximum rate of flow at Rochester, 21,000 cubic feet per second. Flats between Mt. Morris and Rochester flooded.

1890, Sept. 10th to 13th. Maximum rate of flow at Mt. Morris 20,400 cubic feet per second. From 3 P. M. of 10th to 9 A. M. of 14th, no less than 3.5 billion cubic feet of water passed Mt. Morris.

1889, June 1st. Day following the Johnstown flood, water over the flats at Avon, Rush, etc. Maximum rate of flow at Rochester not above 20,000 cubic feet per second. Little or no damage done at Rochester.

1875, March 16th. Ice gorge at Clarissa street bridge, Rochester, setting water back in Erie canal and flooding certain districts. Maximum rate of flow at Rochester not above 25,000 cubic feet per second, except for an hour or two during passage of ice gorge, when it may have reached 35,000 cubic feet per second. Most serious flood ever known at Rochester.

1865, March 17th to 20th. Long continued cold weather and heavy snowfall followed by a sudden thaw accompanied by rain. Nearly the entire central portion of Rochester put under water and damages probably exceeded $1,000,000. Maximum rate of flow at Rochester estimated at 54,000 cubic feet per second.

1857, February 8th. Flood occurred which carried away piers of Main street bridge.

1835, October 23rd. Greatest flood ever known up to this time. Water on the Genesee flats 6 to 8 feet deep. Maximum rate of flow at Rochester estimated at 36,000 cubic feet per second.

1813, June 20th. Rained for three or four days about June 15th to 18th, and on June 19th, rain fell in torrents. "Seldom had such a storm been witnessed in the country." Colonel Rochester's sawmill carried away.

"From 1865 to 1902, a period of thirty-seven years, no seriously destructive flood occurred at Rochester, although there were several at Mt. Morris" (p. 69, H. Com. Rept.). Immunity at Rochester was mainly due to storage over the flats above Rochester and lack of heavy rainfall at the critical time.

The Rochester Flood Commission of 1905, concluded, p. 68, "Sometime there may be a flood of at least 60,000 cubic feet per second at Rochester."

Conclusions Regarding Genesee River Floods.

1. Serious freshets caused by heavy rainfall may occur at Rochester and over the Genesee flats between Rochester and Mt. Morris at any time from March to October inclusive.

2. Twice in the past century, once in March, 1865, again in July, 1902, the rate of discharge at Rochester has been greater than existing river channel could safely convey and large areas within the city have been inundated, particularly in 1865.

3. The widespread inundation and great damage of 1865 were caused by a flood of much smaller volume than is likely to occur at some future time under a combination of the causes which have heretofore within the historic

period come singly, such as exceptionally heavy rainfall on ground previously saturated or rendered impervious by frost.

4. The gagings of rate of flow have apparently been somewhat crude and inexact, but accepting the quoted estimates as correct, it appears that a rate of discharge at Rochester greater than 40,000 cubic feet per second causes great damage, with danger of greater damage than has heretofore occurred, as for example, if a jam of trees, ice or debris should occur in the archways of the bridges at Rochester.

5. Floods giving rate of flow of 20,000 cubic feet per second at Rochester may submerge large areas of the flats between Mt. Morris and Rochester.

6. A flood rate which measures 40,000 cubic feet per second as it passes Mt. Morris may become so modified by spreading out over these flats, by its temporary storage and delay thereon, that notwithstanding the drainage area at Rochester is 2.3 times as great, the rate of discharge in cubic feet per second at Rochester may be only about half as great as at Mt. Morris.

7. The project for flood relief on the Canaseraga flats by straightening the channel has not yet been studied by means of recording gages on the Genesee and its main tributaries, or with precision to show just what bearing quicker drainage for local relief this will have upon the rate and height of flood discharge at Rochester and on the flats immediately above, and in absence of precise data, I venture no opinion on this question. It is believed by those who promoted this project that this cutting of a new channel and straightening the Canaseraga will hasten the transit of the Canaseraga water and get it out of the way largely before the flood flow from above Portageville arrives.

According to the Portage or the Mt. Morris storage reservoir projects presented in the State Engineer's Reports of 1896 and 1895, respectively, it was proposed to discharge the water from the storage reservoir at such a rate as would produce a substantially uniform flow of water for power at Rochester throughout the year. This reservoir, about 100 feet in total depth, would ordinarily be filled to overflowing in April and in years of ordinary rainfall would have become drawn down only a few feet by the date of July 6th, on which date the great flood of 1902 occurred, and if the proposed Portage reservoir be operated, according to the schedule plainly proposed on page 713 of Mr. Rafter's report of 1896, this storage reservoir thus conserved for power supply would have been so nearly full on the occasion at least of some of the great floods of March 2, 1902; April 4, 1896; March 20, 1894; June 1, 1889; March 16, 1875; March 17, 1865; June 20, 1813, that it could have served only partially to retrain and lessen the flood at Rochester or in the valley below Mt. Morris.

Higher Dam and Deeper Reservoir Now Proposed.

I have therefore as a first study proposed to build the dam, say, ten feet higher and to reserve ten feet or twenty feet at the top of the reservoir, where its area is greatest, solely for flood relief, with a strict rule that the reservoir should after a flood be emptied as rapidly as the river channel could carry off its water without overflowing the banks until the reservoir is drawn down to this power level, ten or twenty feet below the spillway crest, so that the emptied portion of the reservoir should stand ready to restrain whatever rainfall of dangerous proportion might come next.

The precise depth to be thus reserved for flood control, whether ten feet or twenty feet or more, has not been worked out, for I consider many more data and observations all along the flooded region are first desirable.

It would be well worth the cost to install and maintain a series of at least six self-recording river stage registers — one at Rochester, one at Mt. Morris, one at Fillmore, one near the upper end of the Canaseraga Valley, and two at intermediate points — by which the relative time of passing of the flood wave could be observed and permit of a more complete study of the progress of the flood. In the absence of such observations, estimates are uncertain about the precise effect on flood heights of the quickened flow on the Canaseraga or the retarded flow above Portage, save that it is sure beyond question that all detention of flood water behind the Portage dam would aid materially in flood relief below Mt. Morris and also in the Canaseraga Valley.

It appears from the report of the Flood Commission of 1902 that the solution of the problem of flood control at Rochester was by no means fully worked out or even attempted by its members. They chiefly collected some facts as to what had happened. This is a large and many-sided problem and requires more surveying and more study of local conditions than I have been able to give.

The widespread destruction and danger likely to follow a repetition of such floods as have already occurred, or the far greater flood which plainly is likely to come at some future time, warrant the expenditure for fully studying this problem.

PLAN OF PORTAGE WORKS PROPOSED.

The main features are as shown by the plans on plates 22, 23 and 24.

First. A dam three-fourths of a mile upstream from the upper Genesee Falls, entirely outside the limits of the land purchased by Mr. Letchworth, and forming a part of the Genesee Park. This is made of an arched form resting on solid ledge abutments, for strength as well as for better architectural effect. An exceptionally long spill way is provided at the westerly end, so that the greatest flood may be discharged with a small increase in height of reservoir.

The height of dam is proposed at an elevation ten feet greater than that proposed by Mr. Rafter, in order that there may be a greater reserve available for flood control, in case a flood should occur while a large volume was being held in storage for power purposes.

Second. Sluiceways are provided in this dam, such that any desired quantity may be withdrawn for scenic purposes over the Genesee Falls. These sluiceways would also serve for rapidly lowering the water in the reservoir to a depth of about ten feet below the spillway level, immediately after the peak of a freshet on the main river had passed, so as to prepare storage space in the top of the reservoir as soon as possible against chance of a second flood.

The dam is to be of concrete, and except for the addition of the arched form, is proposed to be of substantially the same type as those recently designed for New York city's water supply at Ashokan and Kensico.

The elevation of these sluiceways and the elevation of the intake to the proposed power tunnel, are to be set so high that the reservoir cannot be

emptied below elevation 1,120, thus leaving at all times in view from the dam a lake, half a mile or more in length upstream and of substantially the full width between the bluffs, this reserve being provided for as a pleasing feature in the landscape and with no noteworthy detriment to the storage reserves for power and flood control. The intake for the proposed power tunnel to be at a still higher level, so as to cause a reserve in even the most severe drought sufficient for a flow of from 100 to 200 cubic feet per second during the hours of daylight for about 100 days, which cannot be withdrawn for power.

Two alternative sites for a power-house have been surveyed, both of which are downstream from the lowest limit of the Letchworth Park. Up to the present time, study has been mainly concentrated upon the one farthest downstream, since this promises much larger power and greater ultimate economy. This is about three miles down the course of the river from the lower fall and far beyond the limits of the park.

At this lowest site, the river level is about elevation 665, and as the ordinary working level in the proposed great lake above Portage would be about 1,190, the gross fall is 525 feet.

This is about 90 feet greater than the gross fall available at the alternative site one-half a mile downstream from the lower falls, but a part of this difference would be lost by friction in the greater length of tunnel.

The intake for the proposed tunnel is about three-fourths of a mile away from the dam site, going easterly along the north shore of the basin, and the tunnel nowhere runs within about half a mile of the outside limits of the Glen Iris Park.

This tunnel is proposed to be of about 15 feet in diameter, and although borings along its course have not yet been made, it appears probable from a study of the outcrop of ledge, that by keeping the tunnel level down nearly to the power-house elevation, excellent rock will be found all the way. An exceptional structure for a surge shaft is proposed at the downstream end of this long pressure tunnel.

Much study has been given to its design, and it is believed that by use of the form designed all trouble in governing the speed of the turbines or in troublesome waves in the long conduit or in waste of water, can be avoided, and that the full reservoir head can be made available for power, less, of course, the friction loss.

YIELD OF DRAINAGE AREA ABOVE PORTAGE, WITH STORAGE.

The drainage area above Portage contains substantially the same number of square miles as that above Conklingville, but yields much less water, because of the rainfall in this region being smaller and also because of the proportion of the rainfall lost by evaporation being larger, due to the general deforestation of the country for agricultural purposes.

A careful study of the rainfall records and of the gagings of stream flow, made by the mass curve method as already described, indicates that the mean flow of water available for power purposes after making a reservation for scenic purposes at the Genesee Falls, will be only about one-half as great as at Conklingville.

On the other hand, the fall of water is more than twice as great, with a result that the total output of electrical power from the Portage reservoir available for delivery at Rochester, Mount Morris or elsewhere within a radius of fifty or seventy-five miles, is somewhat greater than that available from the proposed Sacandaga power-house.

At the Portage reservoir as in the case of the Sacandaga reservoir, it is not a necessity that the tunnel and power-house be built at the same time as the dam and storage reservoir. They could be built five or ten or twenty years later or whenever desired, and meanwhile the State could utilize the storage reservoir for the increase of present water powers at Mount Morris and Rochester under a proper payment, and to a very noteworthy extent the reservoir would meanwhile also serve for flood control, and during this period while so used, all the water of the river would pass over the Genesee Falls, and the volume flowing over the falls during the vacation or tourist season from July first to October first, would be far greater than under present conditions.

Our estimates by the mass curve method as already described, and after some consideration of the conditions that affected the accuracy of the stream flow gagings, show that a total yield of 800 cubic feet per second, twenty-four hours per day, seven days in the week, may be relied on throughout years as dry as 1895, and a study of the rainfall records indicates that no year of smaller rainfall or smaller stream flow than 1895 has occurred on the Genesee river during the historic period.

ESTIMATE OF POWER.

The power that the storage would add at Mt. Morris and Rochester has been already estimated on page 194.

The power that could be made available in the projected Portage power-house at site B., the lower site, is estimated as follows:

Ordinary or mean level in reservoir	1,190 feet.
Water level at tailrace	665 "
Gross fall	525 "

Tunnel about 3¾ miles in length or about 20,000 feet.

Probable average loss of head in tuunel, etc., not over	15 feet.
Ordinary net fall	510 "

To be safe call this 500 feet.

If average available flow in a series of dry years after allowing water for scenic purposes as described on p. 188 is 750 c. f. s. the power will be $\frac{750 \times 62.4 \times 500 \times 75\%}{550}$ = abt. 32,000 net twenty-four hour, seven-day horse-power.

With a load factor of 40 per cent., this becomes for use in ordinary working hours, 80,000 mechanical horse-power on the turbine shaft.

At 95 per cent. efficiency, this would generate 56,800 kilowatts, and at 85 per cent. efficiency of conversion and transmission, this would deliver at the consumers end 68,000 horse-power in ordinary working hours for manufacturing purposes throughout a dry year; with a larger diversion of water for scenic purposes at Genesee Falls, the yield of power would be correspondingly less; 700 cubic feet per second would yield 63,500 horse-power.

Since as already stated, the estimates of flow of river are probably somewhat low, it appears entirely conservative to speak of this project as capable of yielding 32,000 horse-power of twenty-four hour seven-day power on turbine shaft, or of delivering 65,000 horse-power to consumers under a 40% load factor.

CONSTRUCTION PROPOSED FOR PORTAGE DAM.

The accompanying drawings show the general characteristics of the structures proposed so fully that little further description is necessary.

A system of drainage for the interior of the dam is provided, consisting of a series of wells about two feet in diameter spaced about fifteen feet apart, rising from near the bottom to above the water level and communicating with galleries at top and bottom, all ordinarily closed to circulation of air but arranged so that access could be had for inspection. These wells would be formed by molded blocks of porous concrete imbedded as the building of the dam progresses. They are spaced a substantial distance back from the water face and intended to intercept any of the little leakage that is likely to seep through concrete under great pressure, here and there, however great care be taken. The purpose of intercepting this is to prevent possibility of stresses of hydrostatic uplift, particularly when escape of moisture from outer face might be sealed by frost. This dryness of outer face tends to its durability under frost action and avoids the unsightly appearance and discoloration due water, often seen on high masonry dams.

The sluiceway gates are planned on the Venturi principle in a novel manner in order to save in cost, to make them easier and quicker to operate and in order to quiet the discharge.

It is proposed to operate them on the hydraulic press principle, obtaining the pressure from the reservoir. Since gates operating under a head so great as given by the full reservoir and without back pressure are liable to chattering or to destructive vibration, a special design of gate valve is proposed in which it is believed quiet action can be secured by avoiding projecting lips and by supporting the seat in a novel manner.

The outer base of the dam is to be shielded from extreme temperature strains or frost action by blanketing it with earth and riprap, and a molded base course is planned for architectural effect.

There is an admirable opportunity to build the spillway channel on such declivity and with such a steep slope that its gorging by ice or by flood debris will be impossible and that the destructive energy of the great volume liable to come through it in a great freshet, can be largely absorbed by eddies or water cushions.

If it should later be deemed allowable to build at the more economical site nearer the upper falls within the park limits, proposed by Mr. Rafter, I would recommend adherence to the general design shown in these drawings rather than the earlier designs.

Scenic Interest Along New Railroad Location.

The new location selected for the railroad in climbing to the higher level above the proposed reservoir, is designed to preserve all the scenic interest of the present line and take a course such that the best possible view of the dam and the lake and of the outflow in time of flood, will be had from the trains. Those who must hurry on, as well as those who can stop over at Portage, should have opportunity to enjoy this beautiful scenery.

CHARACTER OF SUBSTRATA AT THIN RIM OF PORTAGE BASIN.

In the zeal of certain estimable men without engineering experience to prevent any encroachment whatever upon the beautiful Letchworth Park, statements have been made that a part of the rim of the proposed basin or reservoir, lying about three-fourths mile westerly from the proposed dam site, is composed of dangerous quicksand. The basis for this statement is that geologic study shows the river once ran through a different channel from that now occupied, a deep gorge now deeply filled, and there is a slowly shifting bank, over which the Pennsylvania railroad runs, close beside the present river gorge and about a mile distant from the locality in question but apparently on the line of the same ancient channel. Another basis for this idea is found in the statement that years ago the railroad abandoned an attempt to tunnel through the narrow portion of the rim in question because of finding quicksand. All this evidence is plainly nonconclusive.

I have, therefore, given special attention to this matter of the safety of the rim of the basin by having the ground carefully contoured and by having numerous deep test borings made at many points scattered over this small area of debatable ground. The sliding bank of fine, wet sand and clay nearer the river has also been studied.

Ours are the first borings known to have ever been made for actually finding out what the truth is about the substrata in this locality near the rim of the basin.

A line for borings was laid out as nearly as practicable at the thinnest point in the natural rim of the basin, located about three-fourths mile northeast from the dam site. Four holes were bored at the locations shown on Plate No. 21. The precise locations were controlled somewhat by the location of road and ownership of land, so they vary a little to one side from the shortest line. The holes were placed in the gully along the line of supposed weakness, pointed out to the Commission at the time of its visit. The borings were made under a foreman experienced in test borings, and check records were kept by one of the assistant engineers. Bed rock was not reached in any of these holes, although the deepest was 150 ft. deep to elevation 1084.

In general, the samples were washed up and caught in a tub, and although some care to avoid loss of the finest particles was taken, this method tends to exaggerate the porosity. A few "drive samples" were taken from some of the later holes, and these are unmistakably a hard, caking, blue clay. Samples were taken at each five feet increase in depth, when adding each length of casing, but after examining and making record, were not preserved unless a change of material was met. Samples were preserved for reference from each day's work, and from each change in material. Daily reports were sent in by the drill foreman.

Every one of these deep samples concurs in showing extremely fine close-grained impervious material well adapted to forming a watertight embankment, considering the great horizontal thickness of the natural dam.

The drill foreman followed popular terminology in classing the deep samples nearly all as "blue clay," but the material also partakes largely of the characteristics of an extremely fine sand, or "rock flour."

From the topographic sheet plate No. 19a it will be seen that the thickness at water level at narrowest point, on proposed flow line at elevation 1,210 is 1,800 feet. On the section shown, Plate 21, it is 2,200 feet. With water down 25 feet, the horizontal distance is 3,200 feet.

The rise of the natural ground above proposed high water in the reservoir is about 100 feet and the thickness of the natural dam, having this great super-elevation is about 500 feet at its thinnest point.

The ground water does not sink down, but the surface water comes out to edge of steep slopes above the proposed high water level on the downstream side at elevation 1,220, or comes out at elevation 1,215 on the reservoir side.

Substantially everywhere below the proposed high water level in the reservoir, the material was classified by the superintendent of borings as either "hard pan" or "blue clay."

From examining the samples, I find that most of those listed as sand are so extremely fine, that as they naturally lie in large masses and including the fine particles lost in the process of wash-boring, these sands would be impervious in the sense in which the word is used by practical men, the grains being mostly 1/500-inch in diameter.

The general results of the borings are shown in plate No. 21 of the drawings, and so far as they go, *they show the conditions to be entirely safe for the work proposed.*

As a matter of fact, although this place may look thin to one who stands on the Erie Railroad grade, or stands in the highway a hundred feet higher than the proposed high water mark, but without having marks to show where the water level would intersect the bank, it is actually more than one-third of a mile thick at the high water level at its narrowest point. The word "quicksand" has been so persistently repeated by one of the gentlemen who has written upon this subject, that I have taken pains to secure expert opinion in the classification of the boring samples returned as clay, and in order that anyone technically familiar with problems of percolation might reassure himself concerning the imperviousness of the material, have had microscopic measurement made to show the quality of much of the material classified as sand.

It will be noted that the particles are extremely fine, and those familiar with such problems will recognize that the rate of percolation in such material in such great width of embankment would be practically negligible.

This portion of natural dam so far as yet explored appears abundantly safe in comparison with such precedents, for example, as is found at the north dike of the Boston Metropolitan Water Works, the proposed Isthmian Canal dam at Gatun, and in sundry other engineering works.

Since extremely fine sand sometimes looks very much like clay, and since expert foremen of borings sometimes classify material as clay, which chemically is not clay, six representative samples from the Portage borings were sent for classification to experts familiar with the interpretation of borings. Their reports are as follows:

Portions of the same samples were also tested for size of grain, with results given below.

SIZE OF SAND GRAINS.

BORING SAMPLES FROM PORTAGE, N. Y.

Size of grains is given as diameter in decimals of an inch. Measured under microscope with micrometer eyepiece by K. Whitman, Jr., February 19, 1908.

Of Samples Sent to Experts.

No. 1 or A. Hole 3, sample 7. Size, .003 to .005.

No. 2 or B. Hole 5, sample 8. Mixture of fine material, size, .0001 to .0005, with some coarse material, size, .003 to .005.

No. 3 or C. Hole 1, sample 4. Size, .00005 to .0002.

No. 4 or D. Hole 5, sample 4. Size, .006 to .009.

No. 5 or E. Hole 5, sample 7. Mixture of fine material, size, .0001 to .0007; with coarser sizes, .003 to .05.

No. 6 or F. Hole 4, sample 5. Size, .001 to .004.

Of Other Samples Preserved for Reference at Albany Office.

Hole No. 1.

Sample No. 2. Size, .003 to .007.
Sample No. 3. Size, .00005 to .0002.
Sample No. 4. Size, .00005 to .0002.

Hole No. 2.

Sample No. 3. Mixture, coarse, .003 to .005, with finer material, .0001 to .0005.
Sample No. 4. Size, .00005 to .0001.
Sample No. 5. Size, .00005 to .0002.

Hole No. 3.

Sample No. 2. Graded material, .003 to .1 or .2.
Sample No. 3. Graded material, .05 to .5.
Sample No. 4. Size, .002 to .006 and small amount coarser material, .03 to .1.
Sample No. 5. Mostly .00005 to .0001, with some .0005 to .002.
Sample No. 6. Size, .0001 to .0008.
Sample No. 7. Size, .003 to .005.
Sample No. 8. Size, .0001 to .0005 with some .002 to .005.
Sample No. 9. Mixture, .0001 to .0005 and .002 to .004.

Hole No. 4.

Sample No. 1. Size, .002 to .008.
Sample No. 2. Largely .0001 to .0005 with some .001 to .002.
Sample No. 3. Size, .003 to .005.
Sample No. 4. Size, .0001 to .0003.
Sample No. 5. Size, .001 to .004.
Sample No. 6. Size, .00005 to .0003 with coarser material graded from [illegible].
Sample No. 7. Graded from .0001 to .1.

REPORT ON PORTAGE RIM SAMPLES BY W. O. CROSBY, GEOLOGIST.

DEPARTMENT OF GEOLOGY,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
BOSTON, MASS., *February* 4, 1908.

MR. JOHN R. FREEMAN,
Consulting Engineer:

In accordance with your instructions, I have examined six samples of material from drill borings recently sent me from Albany and I submit herewith my conclusions as to the character and proper classification of the materials.

It will promote clearness and convenience to refer to the following:

General classification of detrital materials.	Approximate diameter of grains in millimeters.	Diameter of grains in decimals of an inch.
1. Coarse gravel	.....	.....
2. Fine gravel	.....	.....
3. Coarse sand	.....	.....
4. Medium sand	.....	.....
5. Fine sand	0.45	.0177
6. Superfine sand	0.28	.0110
7. Quartz flour	0.16	.0063
8. Superfine quartz flour	0.08	.0031
9. Clay	.....	.....
10. Boulder clay or till	.....	.....

In general usage, quartz flour (7, 8) is reckoned as clay. It is the principal constituent of even the most plastic glacial clays; but it is also often quite free from a true clay base.

SAMPLE A.

Superfine sand (6), composed almost exclusively of subangular and fairly uniform grains of quartz, with no appreciable amount of clay. The gray color indicates a source below or near the water level; and the grain is fine enough to give it a low filtration rate, or make it relatively impervious.

SAMPLE B.

A mixture of superfine sand, quartz flour and clay (6, 7, 8, 9). The sand largely predominates; and the clay does not exceed five per cent. of the whole. It is much more highly composite and more impervious than No. 1, and probably from a deeper source relatively to the water level. The composite character and especially the clay must make this material practically impervious.

SAMPLE C.

An intimate mixture of quartz flour and blue clay (8, 9). In other words, a blue or unoxidized glacial clay — a typical brick clay. Examination with the microscope and by washing shows that in spite of its plasticity it is chiefly composed of superfine quartz flour, the proportion of true clay base probably not exceeding 25 per cent.; but this is sufficient to make it highly impervious.

SAMPLE D.

Medium and fine sand (5, 6) only a trace of quartz flour and no clay. Its relative coarseness, and the uniformity of grain, make it highly pervious and a good water-bearing sand-while the buff tint suggests a source above the water level for this sample.

SAMPLE E.

A highly composite sand, varying from fine gravel (2) to superfine sand (6), with little or no quartz flour or clay. In spite of its composite character, it is, apparently a good water-bearing sand; and the dark gray color shows that it has come from well below the water level. The statements as to the water-bearing character of this and other sands are, of course, based upon the assumption that no appreciable amounts of clay were lost in prosaring the samples.

CLASSIFICATION OF CERTAIN SAMPLES OF SAND OR CLAY FROM PORTAGE, N. Y.

N. Y. BOARD OF WATER SUPPLY,
LABORATORY, 147 Varick Street, *February* 7, 1908.

DEAR SIR.—I send the following report of examination of three (3) samples of clay marked "State Water Supply Commission No. B" and "State Water Supply Commission No. C." The samples were turned over to Mr. Gaines for the chemical and physical tests. The size of sample was insufficient to make any tests by elutriation, or ordinary mechanical analysis with sieves. I quote from Mr. Gaines' report, as follows:

"Each of the samples responded to the tests by which clays are usually recognized, and they may be therefore classified as clays.

"The samples were plastic in the state in which they were received, and became hard and brittle on drying. Each of the samples consisted in part of collodial substances.

"After drying at 130 degrees C., Sample B was found to contain 5.54 per cent. water of hydration and Sample C 5.84 per cent. water of hydration.

"Chemically, both samples consisted in part of hydrous aluminous silicate, or the predominant ingredient of ordinary clay.

"The test by water of hydration alone would be insufficient to pronounce these materials clays. Pure, high-grade clays contain a minimum of 12 per cent. water of hydration: mixed sandy clays may run as low as 3 per cent. or 4 per cent."

There are two general groups of clays; residual clays, those formed in place; sedimentary clays, those deposited from suspension in water. Naturally, the latter afford the best examples of uniform mechanical grading.

For the ordinary purposes of engineering construction I should consider these "clays." I should pronounce them true clays containing an intermixture of rock flour, the latter of which is probably composed of clay forming minerals not completely broken down chemically into clay, and non-clay forming minerals, probably chiefly quartz. Presumably, they are of residual origin.

Respectfully yours,
(Signed) JAMES L. DAVIS,
Assistant Engineer.

APPROXIMATE ESTIMATE OF COST OF PORTAGE RESERVOIR, PLANS OF 1907.

SUMMARY (quantities and prices).

(Estimates on structures mostly by C. T. Rhodes, C. E.)

The following are from rough preliminary approximations and are subject to revision after more complete survey and studies. They are however believed liberal.

Land for reservoir, tunnel and power house	$750,000
Buildings to be removed for reservoir (as estimated by Mr. Shedd)	770,000
Relocation of Pennsylvania Railroad	770,000
Dam and spillway	2,091,000
Highway bridges over reservoir	125,000
Clearing reservoir	25,000
New highways	40,000
Moving cemeteries	15,000
	$4,586,000
Add 10 per cent. for engineering and contingencies	458,000
Total cost of Portage reservoir, estimates of 1907, as developed for storage and flood control and exclusive of tunnel and power plant	$5,044,000

For details see following pages.

COMPARISON WITH ESTIMATES OF 1896.

It will be noted that the above total cost is double that estimated by Mr. Rafter in the State Engineer's Report of 1896, p. 703. In our estimates of 1907, the lands and buildings are estimated at about $870,000 more than in former estimates, a part of this being due to our having added 50 per cent. to the detailed approximate estimate of present market value to allow for extra costs and legal expenses connected with takings for public purposes.

Our estimate for the dam is $1,311,000 more, due in part only to change in site in moving upstream from the limits of the park. For changing the railroad we figure $220,000 more, for bridges and wagon roads $35,000 more.

As previously stated, our present figures rest on incomplete data and are subject to revision. It has been our intention to make these estimates on a liberal basis. The following details will make plain the basis used .

DETAILS OF PRELIMINARY ESTIMATE.

PORTAGE PROJECT.

APPROXIMATE COST OF LAND REQUIRED FOR RESERVOIR, ETC., WITH SPILLWAY AT ELEVATION 1,210 FEET ABOVE SEA.

(See report of inspection by George G. Shedd, C. E., in appendix.)

1,600	acres farm land, $100	$160,000
1,600	acres farm land, $80	128,000
1,100	acres farm land, $60	66,000
1,200	acres hillsides, $40	48,000
2,700	acres hillsides, $30	81,000
600	acres hillsides, $25	15,000
400	acres village property, $500	200,000
500	acres river bed already owned by State	.....
9,700	acres	$698,000
	Expense of condemnation and legal expenses	52,000
	Total	$750,000

AREAS OF LAND TO BE PURCHASED.

FOR RESERVOIR AND DAM.

Area overflowed with water at elevation 1,200	12.3495 sq. miles
Area overflowed with water at elevation 1,210	13.6875 sq. miles

The above figures are from State Engineer's report, 1896, p. 709.

The new dam site is about 2,000 feet farther up-stream than the one proposed in 1896 and the intervening portion of the gorge is about 800 feet wide at elevation 1210, making about 40 acres to be deducted from the above figures.

Disregarding this small amount, and assuming that the increase in area from 1,210 to 1,220 is equal to that from 1,200 to 1,210 gives a result of 15 square miles, or 9,600 acres.

Deducting area of river bed, about 500 acres, leaves net amount to be purchased ..... 9,100 acres

FOR TUNNEL AND POWER-HOUSE — SITE B.

For tunnel, right of way, 18,000 x 50	23 acres
For two shafts and dumping space	8 acres
For power-house and surroundings (above and below cliff, including river diversion) 1,500 x 800	25 acres
For railway to connect with P. R. R. near Lewis' crossing, 15,000 x 100	40 acres
	96 acres

The land for power-house site and the right of way for the tunnel should properly be acquired at same time that reservoir dam is built, in order to avoid possible future complications.

APPROXIMATE ESTIMATE OF COST OF PORTAGE DAM AT NEW SITE ABOUT ¼ MILE ABOVE UPPER FALL.

DAM OF THE ARCHED, RUBBLE CONCRETE TYPE — FACE OF CONCRETE BLOCKS. SPILLWAY AT ELEVATION, 1,210 ABOVE SEA.

83,000	cubic yards earth excavation, $1.75	$62,250
70,500	cubic yards rock excavation, $2.50	176,250
34,600	cubic yards embankment in aprons, 35 cents	12,110
	coffer dam and unwatering site	28,000

268,300	cubic yards (cyclopean) concrete in dam and spillway, $6.50	$1,743.950
300	feet westerly extension of spillway, say	10,000
1,835	cubic yards concrete in bridge, $10.00	18.350
1,210	cubic yards concrete in cornice and parapets, $12.00	14.520
2,400	square yards slope paving, $1.00	2.400
4 48-inch special valves 1 30-inch special valve 1 18-inch special valve		12,000
	Roofing, doors, windows, etc., of gate-house	1.500
	Stairways and railings of gate-house	750
2,160	square yards brick paving, $2.50	5.400
650	square yards granolithic sidewalk (finishing), 40 cents	260
	Weir across river below dam	1,500
	Outfall	1.000
	Pumps and piping for gate valves	500
		$2,090,740

COST OF RECONSTRUCTION OF PENNSYLVANIA R. R.

Computer, C. T. Rhodes, C. E.

Checked by K. Whitman, Jr.

		Jan. 30, 1908
185	acres right of way, $60.00	$11,100
70	acres clearing and grubbing, $30.00	2,100
608,000	cubic yards earth excavation, $0.25	152,000
110,000	cubic yards rock excavation, $1.00	110,000
43,800	cubic yards ballast, $0.50	21,900
49,600	ties, $0.75	37,200
2,080	tons steel rails, $30.00	62,400
250,000	pounds splice bars, $0.015	3,750
25,000	pounds bolts, $0.02	500
100,000	pounds spikes, $0.0175	1,750
18.5	miles track laying, $500.00	9,250
12	switches and stands, $75.00	900
	cast iron pipe culverts	10,000
	masonry arch culverts	10,000
	bridges and piers	275,000
800	lineal feet tunnel in earth with concrete lining, $80.00	64,000
18,000	square yards slope paving, $1.00	18,000
3,000	lineal feet piling, $4.00	12,000
	road crossings and cattle-guard	500
14	miles fencing, $500.00	7,000
15	miles telegraph line, $300.00	4,500
3	stations and freight houses	10.000
1	coal station	500
1	water tank	600
	draining slide section	3.000
	temporary trestling, removing bridges	6,000
	Gross total	$833,950

Credits.

1,900	tons steel rails, $20.00	$38,000	
25,000	ties, $0.35	7,500	
250	tons structural steel in bridges removed, $40.00	10,000	
160	acres right of way, $60.00	9.600	
	stations and other buildings	2.000	
	Less credits		67,100
	Net total		$766.850

PORTAGE POWER PLANT AT SITE B. APPROXIMATE ESTIMATE OF COST

(Estimates by R. D. Johnson, M. E.)

SUMMARY (for details see following pages).

Tunnel, including 2 working shafts and intake shaft	$1,392,000
Excavation for power-house, penstocks and surge pipe shaft	47,385
Concrete for power-house substructure, and linings of penstock, tunnels and surge pipe shaft	102,860
Concrete for transformer house, substructure	18,580
Concrete lining for cliff at transformer house	4,200
Steel work for penstocks, forebay, surge pipe (below ground), re-inforcing bars, etc.	81,965
Gates, valves and operating mechanism	15,485
Power-house superstructure	41,760
Transformer house, superstructure	47,800
Hydraulic machinery	189,000
Electrical machinery	742,500
Cranes and auxiliary machinery	37,000
River wall, river excavation and miscellaneous improvements	16,260
Railroad siding from Pennsylvania Railroad to power-house	54,000
	$2,790,795
Intake works, say	40,000
Surge tank "Study No. 1," all concrete	135,880
Total below dam	$2,966,675
Add 10 per cent. for contingencies and supervision, say	296,668
	$3,263,343
Add for transmission lines, equivalent to conveying 50,000 kilowatts to Rochester, say	800,000
Total for power plant, tunnel and transmission line about	$4,063,343
Adding to this the cost of the reservoir and dam and accessory works	5,044,000
Total cost for complete Portage development	$9,107,343

TUNNEL (fifteen feet diameter) SITE B — PORTAGE.

Allow 12 inches for average thickness of concrete.

Excavation at 8½ yards per foot, at $5	$42 50
Concrete, 2 yards, at $9	18 00
Estimated cost per lineal foot	$60 50

Allow for irregular rock, timbering and contingencies, 15 per cent., or say $70 per foot for average conditions.

18,000 feet, at $70	$1,260,000
Two working shafts, say 600 feet, at $120	72,000
Intake shaft, including steel lining, 300 feet, at $200	60,000
Total	$1,392,000

SUMMARY OF DETAILED ESTIMATE FOR POWER-HOUSE, SITE B — PORTAGE, N. Y.

Rock excavation:	
Power-house site, including tailrace, say 2,000 cubic yards, at $1.30	$2,600
For main penstocks from outside face of power-house to end of intake special, 2,000 cubic yards, at $7	14,000
For passage to valve chamber, 550 cubic yards, at $7	3,850
For tunnel for exciter penstock, 35 cubic yards, at $7	245
For riser shaft between elevation 727 and 877, 1,270 cubic yards, at $12	15,240
For feeder head and riser below 727, 2,300 cubic yards, at $3.50	8,050
For diffuser, 850 cubic yards, at $4	3,400
	$47,385
Concrete:	
Power-house substructure, 10,195 cubic yards, at $7	$71,365
Covering main penstocks from outside face of power-house to end of intake special, 950 cubic yards, at $18	17,100
Lining passage to valve chamber, 200 cubic yards, at $8	1,600
Lining around exciter penstock, 25 cubic yards, at $9	225
Lining riser shaft between elevations 727 and 877, 420 cubic yards, at $6	2,520
Lining feeder head and riser below elevation 727, 900 cubic yards, at $9.50	8,550
Lining diffuser, 150 cubic yards, at $10	1,500
	$102,860
Steel:	
Reinforcing steel in power-house substructure, 119,000 pounds, at $0.045	$5,355
Main penstocks inside of power-house, 246,000 pounds, at $0.0475	11,685
Main penstocks from outside face of power-house to end of intake special, 558,000 pounds, at $0.0625	34,875
Main penstocks, six intake special sections, 46,000 pounds, at $0.07	3,220
Exciter penstock complete, 36,000 pounds, at $0.0525	1,890
By-pass piping, 13,000 pounds, at $0.055	715
Reinforcing beams between penstock at feeder head, 62,400 pounds, at $0.025	1,560
30-foot cylinder at feeder head, 37,000 pounds, at $0.08	2,960
Bottom of 30-foot cylinder at feeder head, 11,500 pounds, at $0.07	805
Riser from tunnel to elevation 875, 196,000 pounds, at $0.055	10,780
Diffuser at end of tunnel, 101,500 pounds, at $0.08	8,120
	$81,965
Gate-operating mechanism, 119,500 pounds, at $0.09	$10,755
Gates, 31,000 pounds, at $0.08	2,480
Valves on exciter and by-pass line, 9, at $250	2,250
	$15,485

Power-House Superstructure.

Superstructure walls, 2,630 cubic yards, at $8	$21,040
Operating gallery, 1,950 square feet, at $0.80	1,560
Supporting wall under gallery, 60 cubic yards, at $8	480
Steel work for roof (projected area), 275 squares, at $20	5,500
Roof covering, superficial area, 306 squares, at $30	9,180
	$37,760
Crane runway for power-house, say	4,000
Total superstructure	$41,760

Transformer House, Substructure.

(Rock excavation, none.)

Concrete:	
Transformer foundations, 1,000 yards, at $6.50	$6,500
Foundation walls, 1,330 yards, at $7	9,310
Foundation end walls, 110 yards, at $7	770
Crane wall (lining cliff), 650 yards, at $6.50	4,200
Transformer skids, say 40,000 pounds, at $0.05	2,000
Total	$22,780

Transformer House, Superstructure.

Roof, 160 squares, at $30	$4,800
Steel in roof, 13,000 square feet, at $0.20	2,600
Floor space upstairs, 13,000 square feet, at $0.80	10,400
Floor space downstairs, 11,000 square feet, at $0.80	8,800
Walls, 2,275 yards, at $8	18,200
Crane runways, lump sum, say	3,000
Total	$47,800

Surge Tank for Study "No. 1."

Concrete, main structure, 3,500 yards, at $15	$52,500
Concrete, catch basin, 1,620 yards, at $6.50	10,520
Steel reinforcing, 155,000 pounds, at $0.04	6,200
Steel tank, weir and down pipes, 393,000 pounds, at $0.07	27,500
Steel riser, 426,000 pounds, at $0.05	21,300
eel splash tanks, 284,000 pounds, at $0.04	11,360
l cof lagging and incidentals, lump sum	1,500
Cost of getting rid of waste water, lump sum, say	5,000
Total	$135,880

SITE B — ESTIMATE OF POWER-HOUSE MACHINERY.

Generators, 10,000 kilowatts on 25 per cent. overload, say 6 at $60,000	$360,000
Turbines, 90-inch runners, say $30,000 each, 6 at $30,000	180,000
Exciters, 350 to 400 kilowatts each, say $7,500, 3 at $7,500	22,500
Exciter water wheels, say $3,000, 3 at $3,000	9,000
Transformers, 11,000 v. to 110,000 v., 10,000 kilowatts on overload, say 6 at $30,000	180,000
High tension switches and apparatus, wiring, etc	100,000
Low tension switches and apparatus, switchboards, etc	80,000
Crane, 50-ton on 75-foot span, at $9,000	9,000
Crane, 10-ton, hand operated, 57-foot span, at $2,000	2,000
Crane, outside, for transformers, 50-ton, 20-foot span	6,000
Auxiliary machinery, air, water, oil, motors, wiring, etc	20,000
Total	$968,500

Railroad Siding from Main Line to Power House.

	Per mile.
Preparing roadbed, say	$10,000
Rails, 120 pounds per yard, at $0.03	6,350
Ties, at $0.20 per foot	1,060
Total	$17,410
Say 3 miles to site B, at $18,000	$54,000

ESTIMATED COST PER HORSE POWER OF THE PORTAGE DEVELOPMENT FROM ROUGH PRELIMINARY APPROXIMATIONS.

First Stage, Portage Development.

From table on page 194 we see that the average possible increase in power at present plants due to the use of all the water from the storage in the Portage reservoir would average about 20,000 net 24-hour horse-power for the dry half of the year, and it would, as a practical matter, increase to about this extent the power economically available throughout the whole year.

The total cost of the Portage reservoir, if all the burden is put on this water power, and nothing on flood control or on betterment of sewerage conditions, distributed over this added power is $\frac{\$5,044,000}{20,000}$, or \$250 per 24-hour 7-day horse-power — a high price; or if this power was used on a 40 per cent. load factor basis, or as 11.2 hour-power, the cost for the mere additional water supply for power at present plants, exclusive of expenditure for new turbines, raceways, etc., would be about \$100 per net horse-power.

Portage Plant.

For the second stage, with the Portage power-house built and the transmission line to Rochester completed, so that about 65,000 horse-power of 11.2 hour power, or power under 40 per cent. load factor, could be delivered to consumers from the Portage power-house, the total cost would be about $\frac{\$9,107,000}{65,000}$ or \$140 per net horse-power delivered from Portage power-house, under 40 per cent. load factor.

But meanwhile the present plants at Rochester and Mount Morris would have made available to them water sufficient to add in all about 8,750 horse-power of 24-hour 7-day power, equivalent to about 22,000 net horse-power under a 40 per cent. load factor, which should carry a part of the above burden.

If we put on this only two-thirds as much as on that generated at the Portage power-house, because of these sites having to meet the expense for raceways and hydraulic machinery, the total cost distributed over 79,600 net horse-power gives $\frac{\$9,107,000}{79,600 \text{ horse-power}}$ about \$115.00 per horse-power as the cost under a 40 per cent. load factor, or for 11.2 hour power, and with no part of the burden carried by the flood regulation and sewerage improvements. This is a reasonably low cost and compares well with many modern developments.

As a first rough approximation similar to that given for the Sacandaga on page 175, we may reckon for the yearly cost, as follows, making the estimate for the second stage, or the combination of reservoir and power house, instead of estimating the yearly maintenance for these separately, as on Sacandaga.

Interest on $9,107,000, at 4 per cent	$364,280
Annual payment to sinking fund, 50-year, 4 per cent., at .655 on total cost of enterprise	59,600
Taxes or equivalent payment to towns at reservoir and power house	15,000
Maintenance of new State highways	5,000
Depreciation and repair on perishable parts, say	50,000
Supervision and maintenance of reservoir	10,000
Power house, supplies, oil, petty repairs and insurance	25,000
" " contingencies and forfeits, say	25,000
" " attendance power house and transmission	75,000
" " supervision and maintenance	10,000
Total yearly charges, reservoir and power house	$638,880

Distributing this over the whole 65,000 horse power under 40% load factor from Portage, plus ⅔ of the 22,000 horse power added at Rochester and Mount Morris, or in all 79,600 horse power of 11.2 hour power we find $\frac{\$638,880}{79,600} =$ $8.03 per horse power per year delivered to consumers for power which could not be produced by steam and delivered, even with cheap coal and large units, for $20.00 per year.

A word of caution is again necessary, that so vast an amount of power could not all be promptly marketed, and that special inducements of low rates for terms of 5, 10 and 20 years would have to be offered to new industries. All rates should be subject to revaluation at end of a term of years.

From what has been said on page 178, and from these costs, it is plain that when developed this great power should be so developed as to get the most out of it for all time, and that the development should be under public control.

CONCLUSION.

In concluding this report I would again emphasize the fact that this is but a progress report and that the small appropriation and the four months of field work have permitted hardly more than a fair beginning of the broad study of how best to conserve the water power resources of the State of New York.

In the two cases selected for special study we have first of all tried to make sure of our data on yield of water, and then to make sure of the extent to which reservoir storage could conserve this flow for use at a uniform rate throughout the year; for upon incorrect answers to these questions, which so vitally affect the quantity of power which a given stream can yield in time of drought, have rested most of the disappointments in water power development.

We have tried to study impartially the question of storage reservoirs for power in the Adirondacks and have found that these reservoirs can be so built as to add to the attractiveness of the Forest Preserve and that whether they make the scenery dismal or beautiful is simply a question of proper plans and supervision.

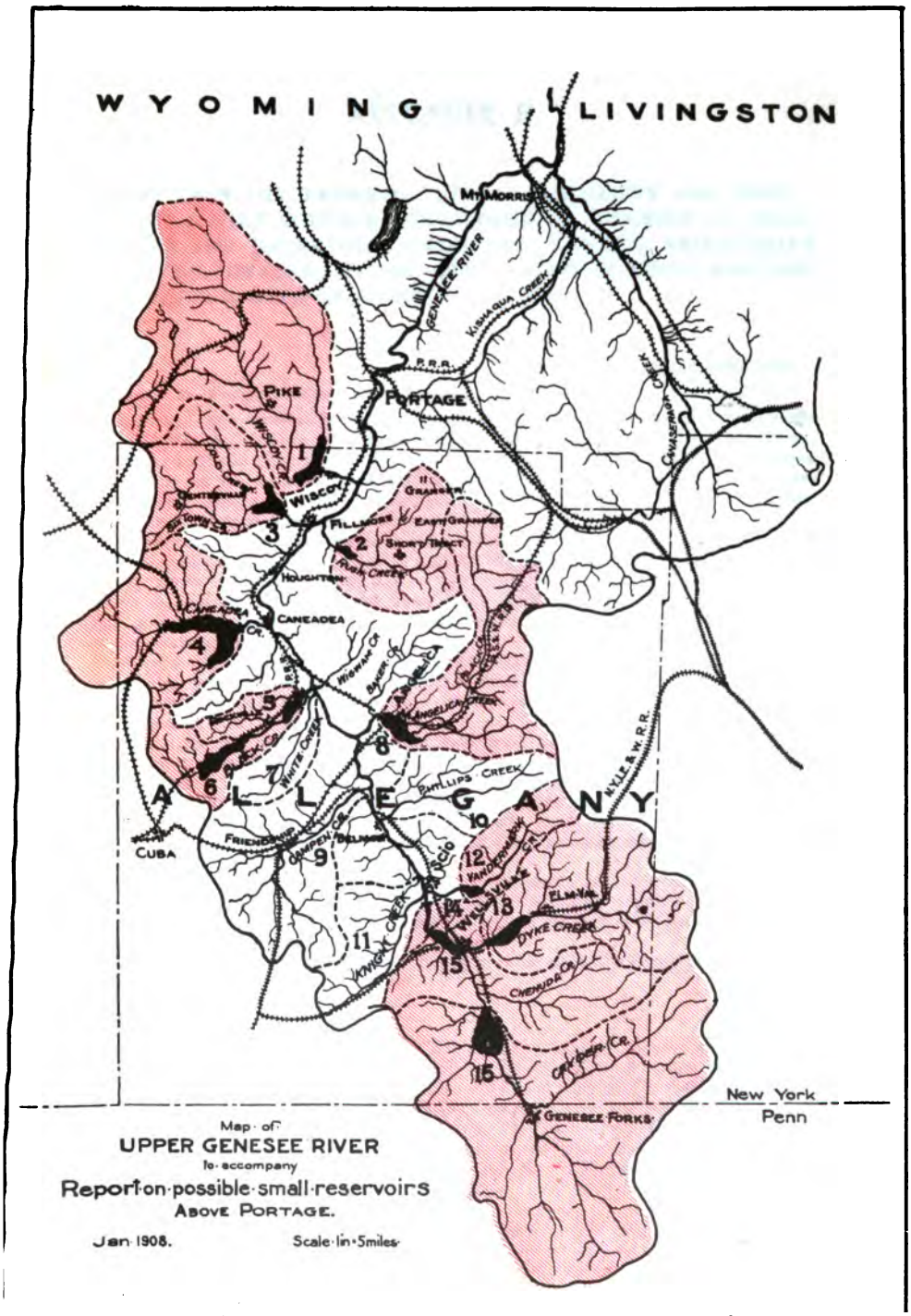
We have tried to study impartially how the Portage Falls could be made to contribute most to the welfare and happiness of the people of the State of New York and have found that result would come when the time is ripe, through a broadly planned reservoir development under State control.

In closing I desire to return thanks, on behalf of the engineer corps, for the kindly interest that all of the members of your Board have taken step by step in all of our work, and personally I desire to give public testimony to the zeal and fidelity of a corps whose members have week after week voluntarily worked long overtime and cheerfully given up holidays that the work of the first season might give some interesting and definite results.

Respectfuly submitted,

JOHN R. FREEMAN,

Hydraulic Engineer.


WYOMING
LIVINGSTON
Mt Morris
GENESEE RIVER
KISHAQUA CREEK
P.R.R.
PORTAGE
CANASERAGA CREEK
PIKE
WISCOY
FILLMORE
EAST GRANGER
SHORTY TRACT
HOUGHTON
CANEADEA
CANEADEA CR.
WIGWAM CR.
BYRON CR.
ANGELICA CREEK
BUCK CR.
WHITE CREEK
PHILLIPS CREEK
N.Y.L.E. & W. R.R.
ALLEGANY
CUBA
FRIENDSHIP
CAMPBEL CR.
BELMONT
CRAWFORD CR.
VANDERMARK CR.
ANGELICA VILLAGE
ELM VAL
DYKE CREEK
KNIGHT CREEK
CHENUNDA CR.
OAK HOPE CR.
New York
Penn
GENESEE FORKS
Map of
UPPER GENESEE RIVER
to accompany
Report on possible small reservoirs
ABOVE PORTAGE.
Jan 1908.
Scale 1in 5miles

PLAT

APPENDIX B.

REPORT UPON THE PROBABLE STORAGE CAPACITY AND WATE POWER THAT COULD BE DEVELOPED BY A SERIES OF SMALL DAMS AND RESERVOIRS UPON THE VARIOUS TRIBUTARIES AND HEADWATERS OF THE GENESEE RIVER ABOVE PORTAGE TOGETHER WITH AN ESTIMATE OF COST.

BY GEORGE G. SHEDD, C. E.

PROVIDENCE, R. I., *January* 16, 1908.

MR. JOHN R. FREEMAN, *Consulting Engineer, Providence, R. I.:*

DEAR SIR.—As requested by Mr. McCulloh in his letter of November 23d, I made a reconnoissance, between November 25th and December 7th, of the Upper Genesee and all the important tributaries above Portage, with a view to determining whether or not the so-called Lord Kelvin plan of constructing a series of reservoirs on the head waters and developing power in small units and at the same time controlling the flood situation was feasible.

The method followed in obtaining this information in the time desired has been to drive up the valleys on the nearest road to the stream, making occasional detours on foot where the stream could not be seen from the road, taking observations of height by aneroid barometer and hand level; width of dam sites and reservoirs when map was not available by eye measurement, and lengths along stream from the best existing maps.

The capacities of reservoirs on the lower portion of stream from Wiscoy creek to Angelica creek inclusive, were computed from the United States topographical maps; above that where no maps are available, capacities were computed from eye measurements, etc., as previously noted.

The designs and estimates from this data have been made upon a conservative basis, using unit prices taken largely from my own personal experience upon similar work. The regulated flow used is deduced by plotting a mass curve of average monthly flow in watershed inches for nine years (1890-1898 inclusive), as given in Flood Committee's Report of 1905 upon the Genesee river, upon which each reservoir capacity was plotted and the maximum rate of flow that could be maintained determined graphically.

While the figures obtained in this way are necessarily only very roughly approximate, I believe that they are accurate enough to determine whether or not further studies should be given to these propositions, which, I understand, is the main object of this reconnoissance.

A statement as to the possibilities on each creek visited follows, taking them in order above Portage.

1.—*Wiscoy Creek, at Wiscoy, N. Y.*

The lower portion of Wiscoy creek below the village of Wiscoy flows through the valley with very little fall. Just above the village is a series of falls over slate ledges, aggregating 60 feet in height. At the head of the falls is a narrow gorge with precipitous sides of disintegrated slate through which the stream flows quite rapidly, falling perhaps 20 feet from dam site to head of falls.

There are several good dam sites in this gorge, the one selected as the best being about 2¾ miles west from the Genesee river and about 1,000 feet below the junction of Wiscoy and East Koy creeks. The drainage area at this point is 114 square miles.

A masonry dam 80 feet high above exposed ledge in the bed of creek, about 600 feet long at top and 200 feet at bottom will create a reservoir of about ¼ square mile in area and would hold approximately 200 million cubic feet of water. The cost of dam would probably be about $320,000, and of reservoir, $20,000 additional, making cost of storage $340,000 ÷ 200 = $1,700 per million cubic feet.

The maximum constant flow with storage would not exceed 69 cubic feet per second. This could be utilized to best advantage by building a power station at foot of falls near the bridge in Wiscoy village, about 4,000 feet below the dam, where a head of 154 feet could be obtained for six months and varying from 154 feet to 74 feet for the balance of the year. This would give 905 horse power at 75 per cent. efficiency for six months and range from 905 to 434 horse power for the other six months, with an average for the year of 787 horse power. The additional cost of developing this power, including penstock, power house, machinery, switchboard and necessary power rights will be approximately $68,000, making a total of $408,000, or $450 per rated horse power of plant.

2.— *Rush Creek, Hume.*

Rush creek rises about 55 feet to the mile, and the banks are from 600 to 1,500 feet apart, so that it is quite evident no storage reservoir of large capacity could be constructed without too great an expense for dam.

The most favorable location noted for the dam is near the road crossing above new Erie railroad trestle and about 4¼ miles east from the Genesee river, where the drainage area is 37 square miles. An earth dam about 40 feet high and 600 feet long with masonry spillway could be constructed for approximately $28,000, creating a reservoir of .07 square miles in area and of 30 million cubic feet capacity at cost for land of $4,000, making a total cost of $32,000 or $1,065 per million cubic feet of storage.

The regulated flow would be 21 cubic feet per second and could be used under a 40 foot head for six months and then varying from 40 feet to 0 for the balance of the year. This would give 72 horse power net for six months and vary from 72 horse power to 0 for six months, with an average for the year of 54 horse power. The additional cost of developing this in power station at the dam would be $5,800, making a total of $37,800, or $525 per rated horse power.

3.— *Cold Creek and Six Town Creek, at Hume, N. Y.*

The only possible dam site for pond water from both creeks is just above the village of Hume, about ½ mile below the junction of Cold creek and Six Town creek, and about 2½ miles west of the Genesee river where the drainage area is 40 square miles. The foundation is of clay and gravel. A dam here would be about 500 feet long at base and 1,000 feet long at crest with a maximum height to 10 feet above water level of 65 feet.

A masonry spillway will be provided about 100 feet long. This dam would create a reservoir of .2 square mile in area and contain 105 million cubic feet. The cost for this dam would be $250,000, and for the reservoir $10,000 additional, making cost per million cubic feet stored $2,470.

The maximum regulated flow would be 28 cubic feet per second, and could be utilized in the power station at dam under head of 55 feet for five months and from 55 feet to 0 for seven months, giving 130 horse power net for five months and varying from 130 to 0 for seven months, with average for the year of 92 horse power. The additional cost of developing this power would be at least $7,500, making the total cost of development $267,500, or $2,050 per rated horse power developed.

4.— *Caneadea Creek, Caneadea, N. Y.*

The most favorable site upon this creek is about two miles west from the Genesee river near the head of Caneadea gorge, which is about 3,000 feet long with precipitous sides of disintegrated slate over 200 feet in height, drainage area 68 square miles.

The site selected would require a dam about 75 feet long at base, and 225 feet, more or less, at top, and would need to be 84 feet high above exposed ledge to furnish reservoir of sufficient size to give complete regulation in the average year. The cost of this dam is estimated at $200,000, and it would create a reservoir of about .9 square mile surface area and 1,000 million cubic feet capacity, costing for land, etc., $50,000, making the total for storage reservoir $250,000, or $250 per million cubic feet stored.

Two schemes are considered in developing the power here. One to build power house at foot of rapids and at the head of the Gleason mill pond, the other to build power house at foot of rapids below the Gleason mill privilege, conducting water in either case by means of a long penstock.

The head under the first scheme would be 125 feet maximum and 41 feet minimum, and would give with the regulated flow of 70 cubic feet per second, a maximum power of 745 net horse power at switchboard and a minimum of 245 horse power with an average of 495 net horse power for the year. This would cost about $53,000, including 4,000 foot penstock, power station and machinery, making the total cost of development $303,000, or a cost of $407 per horse power.

Under the second scheme, the head would be 185 feet maximum and 101 feet minimum, giving a maximum power of 1,100 net horse power and a minimum of 600, with an average of 850 net horse power on switch board for the year. The cost of developing this scheme would be $117,100 additional, including 9,000 foot penstock, power station and machinery and water power rights at Gleason mill, etc., making the total cost of development $367,100, or a cost per rated horse power developed of $384.

5.—*Black Creek, Belfast.*

At a point 1¼ miles west from the Genesee river where the drainage area is 30 square miles, a low earth dam 30 feet high and about 320 feet long with masonry spillway, could be built raising present water level 20 feet at dam and creating a reservoir of .04 square mile area, which would contain 11.5 million cubic feet, costing $12,500 for dam, and $2,500 for land for reservoir, making a total for storage of $15,000, or $1,300 per million cubic feet stored.

The regulated flow would be 13 cubic feet per second, which could be used practically continuously under 20 feet head and develop 22 net horse power at dam, at a cost of $1,460 additional or a total cost for development of $16,460, of $750 per horse power.

6.—*Black Creek, Belfast, N. Y.*

At a point three miles from the Genesee river, there is a narrow section just below Rockville reservoir where a large reservoir could be secured, but at an enormous cost on account of expensive dam and very expensive relocating of the Pennsylvania railroad and also the new Erie railroad cut-off which is now being built up this valley. The drainage area is 26 square miles here.

The dam designed for this location consists of a masonry spillway on main stream 70 feet high and 70 feet long, flanked by earth abutments 130 feet long and an earth dike 3,000 feet long. This would create a reservoir of about one square mile in area and of 538 million cubic feet capacity, and would cost $263,000 for the dam and $48,000 for the land, making a total of $311,000 or $580 per million cubic feet stored, exclusive of cost of relocating railroads. Estimating the relocation of 12 miles of railroad at $50,000 per mile would bring the total cost of reservoir and dam to $911,000, or $1,680 per million cubic feet stored.

The regulated flow is 27 cubic feet per second, and this could be utilized under a maximum head of 80 feet and a minimum head of 20 feet, by building power station about 800 feet below the dam. This would give a maximum horse power of 184 and a minimum horse power of 46, with an average power for the year of 115 net at the switch board. To develop this would cost $14,000 additional for penstock, power station and machinery, making the whole development cost $925,000, or a cost per horse power of $5,000.

7.—*White Creek, Belfast, N. Y.*

The total drainage area of White creek is only 16 square miles, and as it rises about 80 feet per mile for the first six miles with an average width between high banks of from 300 to 600 feet, it is evident that no reservoir could be constructed of sufficient size or at a low enough cost to be considered.

8.—*Angelica Creek, Angelica, N. Y.*

There is no dam site below the junction of Baker and Angelica creeks. Just above the junction of these creeks and below Angelica on Angelica creek is a deep, narrow gorge through which the creek flows over a series of falls. This would make a good dam site, and there would be a large reservoir above, but it would completely wipe out the village of Angelica of about 1,200 inhabitants.

The Pittsburgh, Shawmut & Northern railroad also runs nearly the whole length of the valley, and would have to be relocated. A reservoir here, therefore, could not be constructed for anything like a reasonable figure, even if authority could be obtained to do it, which is very doubtful.

The drainage area is 65 square miles above the gorge. A dam to close this gorge would be of masonry about 75 feet on the bottom, and 200 feet, more or less, at the top, and 50 feet high. An earth dike 400 feet long with a maximum height of 30 feet would also be required to close the gap through which the railroad now runs.

The main dam would cost not less than $65,000, and the earth dike about $16,000. The reservoir created by these dams would be about half a square mile in area and contain 316 million cubic feet of water.

Estimating the land for reservoir at $1,000 per acre, as it is practically all in the village, and the railroad location at $50,000 per mile, and the buildings in the village at $300,000, the cost for reservoir would be $720,000, or a total cost for the storage reservoir, including the dam and dike, of $801,000, making the cost per million cubic feet stored $2,540.

The maximum constant flow of storage is estimated at 57 cubic feet per second, and if the power station is located at foot of rapids, a maximum net head of 95 feet could be obtained for six months in the year with a minimum net head of 45 feet. The power for six months would be 460, and varying the other six months from 460 to 217, making an average for the year of 400 net horse power. The estimated cost of developing this would be $29,400 additional for 2,000 feet of penstock, power station, and machinery, making a total cost for development of $830,000, or $1,800 per rated horse power developed.

9.— *Campen Creek, Belvidere, N. Y.*

The Erie railroad from Cuba to Belvidere parallels this creek for its whole length and as viewed from the train, it did not appear feasible to locate a reservoir of any size on this creek. The valley is uniformly wide (from 600 to 1,000) and with a descent of from 30 to 50 feet per mile. The drainage area is 59 square miles.

10.— *Phillips Creek, Belmont, N. Y.*

I did not go up this creek personally, but from descriptions of residents, do not believe there is anything in it of value for storage purposes. It is said to be a rapidly running stream, flowing through several narrow gorges with no large areas between, suitable for reservoirs. The total drainage area is only 30 square miles.

11.— *Knight Creek, Scio, N. Y.*

The total drainage area of Knight creek is only 24 square miles, and as no dam site or reservoir site could be found within a mile and a half of the mouth, and as the watershed above that point is so small, it was quite evident that nothing of value could be found above there. I did not therefore investigate any further.

12.— *Vandermark Creek, Scio, N. Y.*

There is a possible reservoir site about two miles up from the river where a reservoir, say, 1 mile long and from 400 to 800 feet wide, making a surface area of .114 mile and averaging, say, 10 feet deep, could be secured by building a dam approximately 50 feet high, from 60 to 75 feet long at the base, and from 150 to 200 feet long at the top at head of gorge. The foundation for the dam would be of disintegrated slate.

The dam is estimated to cost not less than $78,000, and would create a reservoir of 30 million cubic feet capacity. The cost for land for reservoir is estimated at $5,600, making a total cost for storage of $83,600, or a cost of $2,780 per million cubic feet stored.

The drainage area above dam is 19 square miles, and the maximum constant flow is estimated at only 11 cubic feet per second. This could be utilized under a head of 70 feet for six months and varying from 70 to 20 feet for six months by carrying penstock about 1,000 feet down the stream to the power station.

The maximum horse power would be 65 and the minimum 18, giving an average for the year of 53. The cost of developing this power would be $6,800 additional for penstock, power station, and machinery, making the total cost of development $90,400, or a cost per rated horse power developed of $1,390.

13.— *Dyke Creek, Wellsville, N. Y.*

The valley of Dyke creek would make an admirable reservoir, as it is broad and flat and the land is practically worthless except for a large oil pumping station, but there is no suitable dam site. The point selected as the most favorable for dam is about 1 mile east of the Genesee river and as estimated consists of a masonry spillway 200 feet long and an earth embankment 1,300 feet long and 50 feet high to the flow line with a maximum height of 60 feet. This would create a reservoir of .36 square mile in area and of approximately 200 million cubic feet capacity.

The cost of dam would be not less than $370,000, and the cost of land for reservoir exclusive of moving railroad, roads and pumping station, would be $11,500, making $381,000 total, or $1,905 per million cubic feet stored.

Estimating the cost of moving Erie railroad about three miles at $150,000, two miles of highway $2,000, and moving oil pumping station $50,000, the total cost for storage would be about $580,000, or a cost per million cubic feet stored of $2,900.

The drainage area is 72 square miles, and the estimated constant flow 52 cubic feet per second. This could be used under a head of 50 feet for four months and with a varying head from 50 feet to 0 for eight months, furnishing 220 horse power at switch board for four months and an average of 110 horse power for eight months, or an average of 146 horse power for the year. The additional cost of developing this for power station and machinery is estimated at $9,000, making a total cost of $589,000, or a cost per horse power of $2,670.

14.— *Main Stream of the Genesee River of One-Half Mile Above Scio, N. Y.*

A masonry dam 10 feet high and about 150 feet long could be constructed at this point, but as it would simply raise the water in the main stream over an area of about .025 square mile and would hold only 3½ million cubic feet of water, it would have no value as a storage reservoir. The cost of this dam is estimated at $6,000, and the land at $1,500, making a total of $7,500, or $2,100 per million cubic feet of storage.

The drainage area is 295 square miles and the maximum constant flow not more than 118 cubic feet per second. This would give constantly 100 net horse power. The cost of developing this power is $5,400 additional for power station and machinery, making a total of $12,900, or $129 per horse power developed.

15.— *Main Stream of the Genesee River About One and One Half Miles Below Wellsville.*

A dam at this point would have to be at least 1,500 feet in length, and as estimated, consists of a masonry spillway section in present channel 200 feet long, 20 feet high, and an earth embankment 1,300 feet long, 20 feet high. This would flow the valley approximately 10 feet deep for 1½ miles upstream, and from ⅛ to ¼ of a mile wide, making a reservoir of about .28 square mile in area and about 78 million cubic feet capacity.

The cost of dam would be at least $81,000, and the cost of land at $100 per acre $20,000, making the total cost, exclusive of the moving railroads, etc., $101,000, or a cost per million cubic feet stored of $1,300. Estimating the cost of moving 1½ miles of the new Buffalo and Susquehanna railroad at $60,000 the

total cost for development would be approximately $160,000, or a cost per million gallons stored of $2,030. The drainage area at this point is 293 square miles, and the regulated flow 155 cubic feet per second.

The head for power purposes would be 20 feet for five months in the year and would vary from 20 feet to 0 for seven months, giving 260 net horse power for five months and varying from 260 to 0 for seven months, making an average for the year of 183 net horse power. The cost of developing this power is estimated at $17,400 for power station and machinery, making a total cost for development of $177,400, or a cost per rated horse power developed of $684.

16.—*Main Stream of the Genesee River About Four Miles Above Wellsville.*

A dam designed for this narrow point in the valley consists of a masonry spillway 50 feet high and 200 feet long, and an earth embankment 1,300 feet long with a maximum height of 60 feet. This would flow a broad valley, say, 1 mile wide in its widest part and about 2 miles long to a maximum depth of 50 feet and an average depth of 20 feet, having a surface area of approximately 1.5 square miles and a capacity of 850 million cubic feet.

The cost of dam is estimated at $370,000, and of land for reservoir $75,000, the moving of Buffalo & Susquehanna railroad 4 miles $200,000, the relocation of 5 miles of highway $5,000, making a total cost, exclusive of moving railroad and highways, of $445,000, or $522 per million cubic feet, and a total cost of $650,000, including removal of railroads, etc., or $765 per million cubic feet stored.

The drainage area at this point is 166 square miles, and the estimated maximum constant flow 150 cubic feet per second, which could be utilized at a head of 50 feet for three months and varying from 50 feet to 0 for nine months, giving 640 horse power for three months and varying from 640 to 0 for nine months, making an average for the year of 400 net horse power. The cost of developing power would be $24,000 additional for power station and machinery, making a total cost of $674,000, or a cost of $1,050 per rated horse power.

The valley above this point is very broad, and no other possible dam sites were found in the six miles between here and the Pennsylvania State line. No investigation was made for Cryder creek, or the main stream above the State line, as, of course, New York would have no authority to interfere with Pennsylvania streams.

The figures given in the previous descriptions are shown in tabular form in tables No. 1 and No. 2, below.

Table No. 1 shows the drainage areas, capacities and cost of storage reservoirs, together with the ratio of cost of each reservoir investigated to Rafter's estimate of cost of storage per million cubic feet at Portage.

Table No. 2 shows the regulated constant flow that can be maintained with maximum and minimum head; maximum, minimum, and average horse power, cost of whole development provided power is developed in connection with storage reservoirs, cost of development per rated horse power of plant and ratio of cost to cost at Portage.

CONCLUSION.

It will be seen from an inspection of these tables that the reservoir site at Caneadea creek is the only one of all those investigated that offers any promise whatever as a storage reservoir, and that the capacity is only 6 2-3 per cent. of the Portage reservoir, while the cost for storage as estimated is 1.44 times the Portage reservoir cost per million cubic feet.

The water power at this site could be developed at lower cost per horse power than at any of the other locations above Portage, excepting only the very small power on the main stream at Scio where 100 horse power could be developed for $129 per horse power, but the maximum constant power to be obtained is only 2 per cent. of that obtainable at Portage, and the cost is 38 per cent. greater per horse power.

The total combined storage capacity of all twelve reservoirs estimated upon, which are all that could be found on a two weeks' reconnoissance, is only 3,362 million cubic feet or 22 per cent. of the Portage reservoir capacity, while the total cost is 1.55 times more than Mr. Rafter's estimates for Portage.

The cost per million cubic feet stored at Portage was estimated by Mr. Rafter in 1896 to be $173, while the cost of the combined storage as estimated above is $1,200 or 6.94 times as great.

The maximum horse power that could be developed from all twelve reservoirs is estimated at 3,708 net horse power; the minimum horse power being 1,082 and the average for the year being 2,847. The total cost of developing this power in connection with the storage reservoirs is estimated at $4,400,000, or a cost of $1,190 per rated horse power. The minimum 7-day 24-hour horse power at Portage is estimated by Mr. Freeman at 30,000, or about 28 times the amount estimated for all twelve reservoirs, or in other words the minimum power for all twelve reservoirs is only 3.6 per cent. of that at Portage. The cost of development at Portage without transmission is estimated by Mr. Freeman at $277.00 per horse power, making the cost of development for the combined twelve reservoirs to be 4.3 times the cost per horse power at Portage.

The value of water power to be obtained from a storage reservoir operated primarily to regulate the flow of the stream cannot be equal to one operated for power purposes only.

In the first case the intention would be to so control the outflow as to give as nearly constant flow as possible regardless of head in reservoir.

In the second case, the maximum power could be obtained by using the power intermittently, never drawing the reservoir down beyond the point where it would not replenish itself before time to start up again. The flow in the stream below would consequently be very erratic, but by operating a number of reservoirs in conjunction during season of low water, it would be possible to keep the power practically constant for the twenty-four hours and much higher than would be possible by operating each independently. By operating in this way, the minimum and average horse power, as calculated in the above table, could perhaps be increased somewhat, as the figures in the table are based on using reservoirs to best advantage for steam regulation. The maximum horse power given, however, would not be changed by this method of operation, and as the cost of development per rated horse power is calculated upon this maximum figure, the conclusions as to value of power would not be changed.

Considered from the hydraulic standpoint alone, I think that we may say with perfect confidence that the Lord Kelvin plan is not feasible and could not with any reason be considered as an alternative to the Portage project.

In considering the electrical features of the plan, I would naturally hesitate to criticise anything suggested by so eminent a scientist as Lord Kelvin, but the scheme of direct current transmission as outlined in the Rochester Democrat and Chronicle of May 3, 1902, is certainly not feasible, and it is contrary to all accepted ideas of transmission and utilization of electrical energy.

As Mr. Hollis French, the well-known consulting engineer, suggests in a recent personal letter, the reporter must have misunderstood Lord Kelvin, and that instead of direct current the new "constant current system" must have been intended. Extracts from Mr. French's letters in which he states some of the flaws in the direct current plan and also outlines the "constant current system," are given below, as also a brief resumé of the Lord Kelvin plan.

As the hydraulic development of the so-called Lord Kelvin plan is the controlling feature, and this is found to be impracticable, it would not seem worth while to go very deeply into the electrical part.

Respectfully submitted,
GEORGE G. SHEDD.

GENESEE RIVER INVESTIGATIONS — TABLE No. 1 — STORAGE AVAILABLE ON TRIBUTARIES ABOVE PORTAGE.

January 12, 1908. Roughly Approximate Estimates from reconnoissance by George G. Shedd, C. E.

	Drainage area, square miles.	Storage, million cubic feet.	Storage per square mile.	Total cost.	Cost per million cubic feet.	Ratio of cost to cost at Portage site.
1. Wiscoy creek	114	200	1.75	$340,000	$1,700	6.1
2. Rush creek	37	30	.81	32,000	1,065	3.8
3. Cold creek	40	105	2.63	260,000	2,470	8.8
4. Caneadea creek	68	1,000	14.70	250,000	250	.9
5. Black creek	30	11.5	.38	15,000	1,300	4.6
6. Black creek	26	538	20.70	911,000	1,680	6.0
7. White creek	16	No reservoir site.				
8. Angelica creek	65	316	4.86	801,000	2,540	8.7
9. Campen creek	59	No reservoir site.				
10. Phillips creek	30	No reservoir site.				
11. Knight creek	24	No reservoir site.				
12. Vandermark creek	19	30	1.57	83,600	2,780	9.9
13. Dyke creek	72	200	2.78	580,000	2,900	10.4
14. Genesee river, one-half mile above Scio	295	3 5	.01	7,500	2,100	7.5
15. Genesee river, one and one-half miles below Wellsville	293	78	.26	101,000	1,300	4.6
16. Genesee river, four miles above Wellsville	116	950	5.11	650,000	765	2.7
		3,362		$4,031,100	$1,200	4.3
Portage development estimates of 1907	950	18,000	19.0	5,044,000	280	

GENESEE RIVER INVESTIGATIONS — TABLE No. 2 — POWER AVAILABLE ON TRIBUTARIES ABOVE PORTAGE.

January 14, 1908. Roughly Approximate Estimates from reconnoissance by George G. Shedd, C. E.

	Rate of draft per square mile available with storage.	Constant flow, with storage available.	Head.		Horse-Power at 75 Per Cent. Efficiency.		Horsepower at 75 per cent. efficiency. average for year.	Total cost of development.	Cost of development per rated horsepower.	Ratio of cost to cost at Portage site.
			Maximum.	Minimum.	Maximum.	Minimum.				
	Cu. ft.									
1. Wiscoy creek	.61	69	154	74	905	434	787	$408,000	$450	1.62
2. Rush creek	.56	21	40	.....	72	.....	54	37,800	525	1.89
3. Cold creek	.70	28	55	.....	130	.....	92	267,500	2,050	7.40
4. Caneadea creek	1.03	70	185	101	1,100	600	850	367,000	384	1.38
5. Black creek	.44	13	20	20	22	22	22	16,500	750	2.71
6. Black creek	1.03	27	80	20	184	46	115	925,000	5,000	18.05
7. White creek		No reservoir site.								
8. Angelica creek	.87	57	95	45	460	217	400	800,000	1,800	6.50
9. Campen creek		No reservoir site.								
10. Phillips creek		No reservoir site.								
11. Knight creek		No reservoir site.								
12. Vandermark creek	.57	11	70	20		18	53	90,000	1,390	5.00
13. Dyke creek	.72	52	50	.....	220	.....	146	589,000	2,670	9.64
14. Genesee river at Scio	.40	118	10	10	100	100	100	12,900	129	0.47
15. Genesee river one-half mile below Wellsville	.53	155	20	.....	260	.....	183	177,400	684	2.47
16. Genesee river four miles above Wellsville	.90	150	50	.....	640	.....	400	674,000	1,050	3.80
					3,703	1,082	2,847	$4,395,100	$1,190	
Portage	.84	800	525	455	.....	30,000	30,000	8,307,343	277	.....

EXTRACTS FROM LETTERS OF MR. HOLLIS FRENCH TO GEORGE G. SHEDD, RELATIVE TO DIRECT CURRENT TRANSMISSION.

With regard to the plan of electrical transmission of power proposed by Lord Kelvin in this case, one recognizes with difficulty, from the description in the newspaper article submitted, any known system. From Lord Kelvin's attitude in other matters, however, there is reason to believe that he refers to the so-called direct or continuous constant current system of transmission as distinguished from that making use of alternating current at constant potential.

Ignoring the reporter's incoherent description of the plan, it may be said that the direct current system has been discussed considerably in Europe where its most ardent advocate is M. Rene Thury, chief engineer of the Campagnie de L'Industrie Electrique et Mecanique of Geneva. Largely through his efforts at least two plants have been installed on the Continent where this system has been adopted.

One of these plants supplies the town of Lausanne, Switzerland, with direct current transmitting about 5,000 h. p. from St. Maurice, a distance of 35 miles, at 23,000 v. potential.

The other plant transmits several thousand horse power at 60,000 v. from Montiers to Lyons, France, a distance of 110 miles.

This plan has also been considered for the great Victoria Falls project where from 150,000 v. to 200,000 v. have been figured on. At the present time, however, it is believed that the Lyons project above referred to is the largest and most important transmission of this kind ever attempted, though some interesting experiments were carried on at Geneva a few years ago, using direct current at seventy thousand volts potential.

It cannot be said that the majority of engineers, particularly in this country, consider this scheme very seriously, but it must be admitted that it has made sufficient headway in Europe to be entitled to a good deal of thought.

Briefly described, it is a system using direct current at a constant strength with a varying potential, just as is used on the direct current arc system in operation in this country though on a different scale. It is, therefore, quite the reverse of the constant potential system where the current varies with the load.

For long distance transmission of any size it means that a large number of generating units must be used, connected in series. Each dynamo generates a constant current at a certain voltage. Two will, therefore, generate the same current, and when connected in series will double the voltage. Three will give thrice the voltage, and so on, the current remaining at constant strength.

The line voltage is thus raised by the necessary addition of generating units to a point as high as is desired for the tranmission.

This plan possesses the great disadvantage of requiring a large number of generating units, which is thus quite the reverse of modern practice of using as few units as possible. It also has the objection of requiring a similar number of units at the receiving end of the line to step down to working voltages. All of these machines, being constant current dynamos, are of course provided with commutators, which are entirely done away with at great advantage in the alternating current system. Altogether the number of machines with this system is greatly in excess of those that would be provided with an alternating current plant, which means that floor space and attendance are at a maximum with continuous current. These machines, moreover, have to be thoroughly insulated from the ground, requiring very careful construction.

On the other hand, the switchboard arrangements are very simple indeed and the use of direct current on the line considerably lessens the problem of insulation and strain on the insulators, which requires such careful consideration in alternating current lines.

As for the question of copper, the inevitable loss in conductors has to be faced whether constant current or constant potential is adopted, because no

amount of figuring can escape Ohm's law. At equal maximum voltage for a given amount of energy transmitted, the full load current on the line is the same whether we work at constant potential or constant current. The difference is that at constant current the energy loss is constant at all loads, while at constant potential the insulation strain is constant.

The relative importance of these two conditions at high voltage remains to be determined.

It may safely be said that for the project under discussion, there is no question but that a proper alternating current system of transmission can easily be worked out along the lines of standard practice in this country, and it may very easily be doubted if a direct current system would offer any advantage in this case, either from point of view of operation or of first cost, especially when it is remembered that the machinery and devices required would have to be imported from abroad for the purpose.

(Signed) HOLLIS FRENCH.

APPENDIX C.

REPORT UPON VALUE OF BUILDINGS INCLUDED WITHIN THE LIMITS OF THE PROPOSED GENESEE RIVER STORAGE RESERVOIR IN TOWNS OF GENESEE FALLS, PORTAGE, GRANGER, HUME, AND CANEADEA.

By GEORGE G. SHEDD, C. E.

January 24, 1908.

MR. JOHN R. FREEMAN, *Consulting Engineer, Providence, R. I.:*

DEAR SIR.— Responding to your request to present a brief report upon the value of all buildings within the limits of the proposed Genesee storage reservoir at Portage, N. Y., I respectfully submit the following outline and results of my estimate.

Each house or building in the five towns of Genesee Falls, Portage, Granger, Hume and Caneadea, within the limits of the proposed reservoir, was visited between December 10th and 23d, inclusive, 1907, and approximate dimensions of all buildings noted, together with my judgment of the value per cubic foot, guided by a carefully prepared and checked schedule of unit values for varying types of buildings.

The values of the buildings thus obtained were checked in as many instances as possible by means of the assessed valuation, or otherwise, as opportunity offered. The information thus obtained is summarized for the five towns in table attached.

It will be noted that, including the village of Houghton, which may not be disturbed, there are 1,096 buildings in all, classified as follows:

349	dwellings.
630	minor buildings connected therewith.
8	churches.
9	schoolhouses.
30	stores.
70	other buildings.

These "other buildings" are principally small shops, quarry sheds, cheese factories, saw mills, hotels, etc. There are no large manufacturing concerns in the valley, the largest being the new plant of the L. C. Roberts Mfg. Co. at Fillmore, where they are just starting in to manufacture concrete machinery.

There are two quarries which would be flooded out: The Portageville Bluestone Co., which is said to do business of about $40,000 to $50,000 a year (gross value of stone shipped) and the Genesee Valley Bluestone Co., now shut down and in the hands of a receiver.

The estimated present market value of all buildings in the five towns is $515,626. Adding 50 per cent. to this value for the extra cost due to condemnation proceedings and other legal expenses, brings the total amount required to purchase this property for reservoir purposes to $773,439.

It will be noticed that this value of the buildings alone is in excess of Mr. George W. Rafter's estimate, in 1896, of the total land damages for this reservoir, which presumably included all buildings. When we add the value of land to be acquired it will be found that my estimate is more than 100 per cent. in excess of Mr. Rafter's figures, but, even with this marked discrepancy, I believe that my figures are conservative and are no more than should be estimated upon to cover all contingencies.

The full details of estimate will be found on sheets Nos. 1-67, inclusive, attached to full report, dated January 23, 1908.

Very respectfully submitted,

GEORGE G. SHEDD.

GENESEE RIVER STORAGE — PORTAGE RESERVOIR — SUMMARY OF ESTIMATE OF VALUE OF BUILDINGS TO BE TAKEN IF RESERVOIR IS CONSTRUCTED. January 22, 1908. George G. Shedd, C. E.

	TOWN OF —					
	Genesee Falls.	Portage.	Granger.	Hume.	*Caneadea.	Total.
Total number of dwellings	74	17	13	207	38	349
Total number minor buildings connected	59	47	55	423	46	630
Total number of churches	4	.....	.....	3	1	8
Total number of schoolhouses	1	1	.....	6	1	9
Total number of stores	3	.....	.....	23	4	30
Total number of other buildings	23	.....	1	42	4	70
Total number of all buildings	164	65	69	704	94	1,096
Estimated present market value	$87,479	$16,410	$11,473	$337,246	$63,018	$515,626
Extra cost due to condemnation proceedings and other legal expenses — say 50 per cent	43,739	8,205	5,737	168,623	31,509	257,813
Total	$131,218	$24,615	$17,220	$505,869	$94,527	$773,439

* Includes 57 buildings, with total value of $72,900. in village of Houghton, which will probably not be disturbed, but is included to be on the safe side.

LAND VALUES AT THE PORTAGE RESERVOIR SITE.

(Our estimate of cost of land for this reservoir is so much larger than the estimate by Mr. Rafter given in the State Engineer s Report of 1896 that in order to justify the reasonableness of these later estimates it has appeared best to state the basis in some detail. The investigation was made by Mr. Geo. G Shedd, C. E., who has had practical experience in bonding of land for power development elsewhere and his report is as follows. J. R. F.)

MR. JOHN R. FREEMAN, *Consulting Engineer, Providence, R. I.:*

DEAR SIR.— In response to your request of December 7, 1907, to make as accurate an estimate as possible, and complete field work by December 25th, of the value of all buildings within the limits of the proposed Genesee river storage reservoir at Portage, I beg to report as follows:

METHODS ADOPTED IN ESTIMATING VALUES.

Before starting for Portage a schedule of values per cubic feet of various kinds of buildings was compiled from the best data at hand. The schedule adopted is as follows:

DATA FOR ESTIMATING APPROXIMATE VALUE OF BUILDINGS.

	Cents per cubic foot.
Dwellings — Frame.	
Cheapest construction, small	4
Ordinary construction	5–8
Best construction, large	8–12
Dwellings, brick	7–10
Barns, frame	1.5–3
Churches.	
Wood, ordinary	5–7
Brick	8–10
Schoolhouses.	
Wood, ordinary	5–10
Brick	8–10
Stores.	
Wood	5–7
Brick	7–9

These values are for new buildings. Depreciation is ordinarily estimated on the frame buildings from 2 to 3 per cent. per annum, and on brick buildings from 1 to 1½ per cent. per annum.

In estimating the cubical capacity of the various buildings the cellar is included, and the height is taken halfway between the eaves and ridgepole, so as to get approximately the actual cubical capacity of the building. Realizing that the error in judgment in adopting a unit value for the various buildings was liable to overbalance any little inaccuracy in estimating the cubical capacity, approximate rapid methods were used, using greater care with the larger and more expensive buildings.

Upon arrival at Portageville on December 10th, my first endeavor was to check this schedule. I soon found that Mr. Michael Joyce, the proprietor of the Genesee Falls House, one of the few monied men of the town, had a large personal knowledge of the cost and recent selling prices of a great many of the houses and property in Portageville, and he very kindly gave me a large amount of data by which I was enabled to check this schedule, which was found to agree very well with the values in Portageville when using a rate of depreciation of 2 per cent. per annum.

Through permission of Mr. Walter McCulloh, consulting engineer, Mr. R. H. Prentice, the recorder in the party of engineers in the employ of the Commission just leaving Portage, was detailed to assist me in measuring buildings, etc.

A check in the valuation at Fillmore was also obtained through Messrs. Warren M. Sweet and Floyd Couch and a number of others who were able to give me exact cost values of different buildings.

The value of real estate in general is quite a little higher at Fillmore than at Portageville, Wiscoy or Rossburg. The selling value of real estate in Portageville for the past few years seems to have been considerably below the actual value of such buildings elsewhere.

In the course of my investigation there I learned of several estates which were sold at rates far below what I would consider a fair market value. For instance, one of the best houses in Portageville, which must have cost $2,500, was sold, together with six lots, for only $800. While this low valuation would undoubtedly be taken into account when purchasing property for reservoir purposes, I did not consider it wise in preparing my estimate to place values very much below what they would ordinarily sell for in normal conditions.

In order to furnish a check upon my estimate the assessed valuation of a large number of buildings estimated was obtained. While I believe the assessors are supposed to assess property for its fair cash value they will tell you that they placed valuation at from 60 to 75 per cent. of the actual value. My observations would seem to place the assessed value approximately at 50 per cent. of the fair market value, and this was confirmed by Mr. W. P. Brooks, the president of the Fillmore State Bank, who probably is as well posted upon actual values of real estate as any man in Fillmore. The assessed value, while useful as a guide, does not always give the true indication of the actual value, as I found a number of apparent discrepancies between the assessed valuation and the actual valuation.

It was the intention to take photographs of all the important buildings estimated, but owing to the weather conditions this was found to be practically impossible. The sky was clear on portions of three days only in all the time that I was out there. However, whenever it was possible, I took photographs, even if the light was not of the best; although the photographs will not be as good as might be desired, they will give some indications of the character of the buildings.

About half the buildings in Portageville, and nearly all in Fillmore, were photographed, and a few of the farmhouses between. A few photographs were also obtained of the village of Houghton.

ATTITUDE OF RESIDENTS TOWARD CONSTRUCTION OF RESERVOIR.

While not exactly in the line of this report, it may be of interest to note what I observed of the attitude of the owners of the property throughout the valley toward the construction of this reservoir.

In 1896, I understand, the people were very bitter and were strongly opposed to this project, but since then several disastrous floods have occurred, notably that of July 5, 1902, which has materially changed the attitude of the people. That flood practically destroyed all the crops of the lowlands, washed out bridges and roads and caused great damage in all the towns along the river. While confidence is returning slowly, at the same time there still remains a constant apprehension of the recurrence of this flood, so that most of the people would now be very glad of the opportunity to sell their places, provided a fair price was offered.

I found very few people who really objected to the building of this reservoir. One of them, Mr. W. P. Brooks, was in 1896 one of the principal opponents to the project and headed a delegation that went to Albany in opposition to it. His principal objection now seems to be that Fillmore would probably ose its prestige as a business center, and that the State, or whoever constructed the reservoir, would not place high enough value upon the condemned property to fully compensate the owners.

Nearly all the farmers throughout the valley would like to see the reservoir constructed, but a number of the business men of Fillmore would probably object to it on account of probable loss of business.

VALUE OF LAND.

The value of the land to be taken was also outside the limits of my investigation, but I will record a few facts noted. Village lots in Portageville of one-fourth acre or less in size are commonly sold for about $100 per lot, although I learned in one instance where a small lot was sold recently at a rate of about $1,200 per acre. This is an exception though and should not be taken as a guide to the ordinary value.

The best farm land, that is, good, rich, tillage land, situated at a level of ten to twenty feet above the ordinary low water, or, in other words, high enough so that the ordinary floods do not reach it, is sold at a rate of from $75 to $100 per acre.

Other farm land ranges from that price down to about $30 per acre, this for the poorest side hill land.

In the village of Fillmore small lots on the main street in the center of the village would sell for perhaps a rate of $2,400 per acre; on the side residential streets for about $1,200 per acre.

One farm directly across the river from Fillmore, was bought at a rate of $117 per acre. This is the highest price of any farm land in the valley that I was able to learn of.

The best farm land away from the village sells for about $100 per acre; good farm land for about $75 per acre and ranging from that down to about $30.

The details of my estimate giving the owner, character of building, approximate cubical capacity of each building, unit value placed upon it, estimated value, assessed value, photograph number and any other facts noted are shown on the fifty-five detailed sheets accompanying.

A summary of all the buildings in each town is shown separately on sheets Nos. 56 to 66 inclusive, and a summary of all the towns is also shown on sheet No. 67.

It will be noticed that the total number of all buildings estimated in all five towns is 1,096, with an estimated present market value of $515,626. Allowing an advance of 50 per cent. due to condemnation proceedings and other legal expenses, the total estimated amount required to purchase for reservoir purposes is $773,439. This includes all buildings which it was thought it would be necessary to purchase.

In a number of instances the buildings are situated from ten to twenty feet above the flow line, but the greater part of the land connected with them was situated below the flow line. Where the buildings were between ten to twenty feet above the flow line and the greater part of the land above that, it was not thought necessary to estimate them.

The main portion of the village of Houghton in the town on Caneadea is included to be on the safe side, but it is quite likely that this village will not be disturbed, as it is between ten and fifteen feet above the maximum flow line.

There are fifty-seven buildings with a total estimated value of $72,900 included in the village of Houghton, which will probably not be required. A few buildings also in the villages of Wiscoy and Fillmore were estimated, which it may not be necessary to disturb. On the other hand, it may be necessary to acquire these on the ground of the removal of all their interests.

The estimated values given in tables are for buildings alone and not for business, although side notes upon value of the business wherever it was obtained, are given on the detailed sheets.

In grouping the various kinds of buildings in the summary, the item "minor buildings connected" is principally barns, granaries, sheds and other small buildings. The item of "other buildings" is principally made up of small shops, quarry sheds, cheese factories, saw mills, hotels, etc.

There are no large manufacturing concerns in the valley, the largest being the new plant of the L. C. Roberts Mfg. Co. at Fillmore, where they are just starting in to manufacture concrete machinery.

In 1896, State Engineer and Surveyor's Report, page 691, Mr. Geo. W. Rafter estimates the total land damages, which apparently includes all the land, estimated at 8,300 acres, and buildings to be acquired, at only $650,000, whereas my estimate of buildings alone is $773,439, which would make my estimate, after value of land is added, more than 100 per cent. in excess of his. Nevertheless, I am convinced that my estimate is conservative, excessive as these figures would seem to indicate.

Respectfully submitted,

GEORGE G. SHEDD.

Town of Genesee Falls, N. Y., including Village of Portageville.

Total number of dwellings	74
Total number minor buildings connected	59
Total number churches	4
Total number schoolhouses	1
Total number stores	3
Total number other buildings	23
Total number all buildings	164
Estimated present market value	$87,479
Extra cost due to condemnation proceedings and other legal expenses, say, 50 per cent	43,739
Total	$131,218

NOTE.—Village lots in Portageville, ¼ acre sell for $100 or $400 per acre. Best farm land sells for from $75 to $100 per acre.

Cheapest farm land $30 per acre.

One small lot in village recently bought at rate of $1,200.

Total assessed value of Real Estate in Genesee Falls, 1907, $363,977.

Town of Caneadea.

	Caneadea exclusive of Houghton.	Village of Houghton Cl. 12,104.	Total including Houghton.
Total number dwellings	8	30	38
Total number minor buildings connected	27	19	46
Total number churches	.....	1	1
Total number schoolhouses	.....	1	1
Total number stores	.....	4	4
Total number other buildings	2	2	4
Total number all buildings	37	57	94
Estimated present market value	$14,418	$48,600	$63,018
Extra cost due to condemnation proceedings and other legal expenses, say, 50 per cent	7,209	24,300	31,509
Total	$21,627	$72,900	$94,527

Town of Hume, including Villages of Vossburg, Wiscoy and Fillmore.

Total number of dwellings	207
Total number minor buildings connected	423
Total number churches	8
Total number schoolhouses	6
Total number stores	23
Total number other buildings	42
Total number all buildings	704
Estimated present market value	$337,246
Extra cost due to condemnation proceedings and other legal expenses, say, 50 per cent	168,623
Total	$505,869

NOTE.—Land in Village of Fillmore sells in small lots on Main St., at rate of $2,400 per acre.
Land in Village of Fillmore sells in small lots on side streets at rate of $1,200 per acre.
Best farm land near village sells for $117 per acre.
Best farm land away from village sells for $100 per acre.
Ordinary good farm land away from village sells for $75 per acre.
Cheapest farm land away from village sells for $30 per acre.

Town of Granger.

Total number dwellings	13
Total number minor buildings connected	55
Total number churches	0
Total number schoolhouses	0
Total number stores	0
Total number other buildings	1
Total number all buildings	69
Estimated present market value	$11,473
Extra cost due to condemnation proceedings and other legal expenses, say, 50 per cent	5,737
Total	$17,220

Town of Portage.

Total number of dwellings	17
Total number minor buildings connected	47
Total number churches	0
Total number schoolhouses	1
Total number stores	0
Total number of other buildings	0
Total number all buildings	65
Estimated present market value	$16,410
Extra cost due to condemnation proceedings and other legal expenses, say, 50 per cent	8,205
Total	$24,615

APPENDIX D.

Law Directing the State Water Supply Commission to Make Studies for Water Power Development.

CHAP. 569, LAWS OF 1907.

AN ACT authorizing and directing the state water supply commission to devise plans for the progressive development of the water powers of the state for the public use, under state ownership and control, and making an appropriation therefor.

Became a law, July 12, 1907, with the approval of the Governor. Passed, three-fifths being present.

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. After the passage of this act, the state water supply commission is authorized and directed to devise plans for the progressive development of the water powers of the state under state ownership, control and maintenance for the public use and benefit and for the increase of the public revenue.

§ 2. The commission shall proceed at once to collect information relating to the water powers of the state and shall devise plans for the development of such water powers, as it deems available and may devise plans for the development of such other water powers as shall be brought to its attention by the mayor of any city, the president of any village, a supervisor of any town or the chairman of the board of supervisors of any county, by a petition verified and filed with it, praying for the development of such water powers. Each such petition shall show and set forth the public purposes to be served by the development therein proposed, and the commission may subpoena the petitioner or petitioners and such other persons as may be deemed desirable to appear be-

fore it and to testify under oath, which oath may be administered by any member of the commission, as to the statements made in the petition and as to other matters relating to the subject thereof.

§ 3. The commission shall present a report to the governor and the legislature on or before the first day of February, in the year nineteen hundred and eight, showing the progress made in its investigation, and shall, if practicable, complete its investigations to such extent as will enable it to devise a comprehensive and practical plan for the general development of the water powers of the state, and shall, if practicable, make the final report of such plan to the governor on the first day of February, in the year nineteen hundred and nine. The governor shall, if practicable, submit the said final report with his own recommendations, if any, relating thereto, to the legislature on or before the twentieth day of March, nineteen hundred and nine. In addition to the number provided by law, two thousand copies of the reports of the commission and the recommendations of the governor shall be printed.

§ 4. If any plan devised by the commission shall include the construction of a dam or dams upon any river or water course, the commission shall ascertain and report as nearly as practicable, the water storage capacity in cubic feet of the reservoir created by each such proposed dam, the recorded rain fall on the water-shed above such proposed dam, and the maximum, minimum and average flow of water, per second, in cubic feet during each month in the year at the point where it is proposed to locate such dam. They shall, as nearly as practicable, estimate the water horse power which would be developed at such proposed dam, the probability of selling such water power, and the probable gross and net revenues from both direct and indirect sources which would be derived from the sale of such power at such proposed dam. It shall also state the relation of such gross and net revenues to the total cost of the construction, annual maintenance and depreciation, including the cost of necessary lands and riparian rights, and cost of acquiring them, and after deducting the annual cost of maintenance and depreciation, the net revenues which would be annually derived therefrom, and the length of time in which such net revenues would pay off the whole cost of

construction lands and riparian rights with the interest thereon. The commission may include such other matters as it shall deem proper, in its report to the legislature.

§ 5. The reports of the commission shall specifically designate and recommend what work in their opinion, should be first undertaken and what work should be thereafter undertaken in the order of the importance thereof to the state.

§ 6. In order to determine the probable gross revenues, the rate of charge for the use of the water horse power under contract for sale shall be based upon the aggregate cost of the development, including the land and riparian rights of the single project, the cost of its superintendence, maintenance and depreciation, and the aggregate water horse power available from that single project, and such rate of charge shall be so adjusted that it will produce a net revenue sufficient to pay, in addition to all costs of superintendence, maintenance and depreciation, the interest upon the bonds as the same shall become due and the principal of said bonds at their maturity.

§ 7. Surveys, plans, maps, calculations and estimates of cost may be made to determine the feasibility of any specific project for water-power development.

§ 8. All final surveys, plans, maps, calculations and estimates made pursuant to the provisions of this act shall be made with the same accuracy that would be requisite if the work and project so surveyed had been ordered to be done, and all surveys, plans, maps, calculations and estimates relating thereto shall be preserved for record and reference.

§ 9. The commission in its reports shall treat the general plan it shall devise and recommend for the development of the water power of the state as one state project and shall treat the specific and separate schemes of development as parts of the whole in order that the legislature and the people may have before them at once the most complete and comprehensive statement of the possibilities of the water power of the state and detailed as well as the aggregate cost of the development in such general plan proposed to be made.

§ 10. The commission in its final report shall also include the draft of a bill for a general law providing for carrying its recom-

mendations into effect. It shall give such particular and detailed description of the several separate and specific schemes of development which are parts of the whole as may be necessary to designate clearly the work to be done, and such particulars as to each project shall be stated separately. Such bill shall include a financial plan providing for the issue of the bonds of the state in such amounts as may be required for paying the cost of the water power development to be made, how and when the bonds shall be issued and sold, the term for which they are to run, the rate of interest thereon, the annual tax to pay and sufficient to pay the interest thereon when due and the principal thereof when the same shall mature. The bill shall provide for the creation of a sinking fund into which the moneys received from the tax by such bill levied shall be paid, and into which the net revenues received from the sale of water power shall be paid, until the moneys in such sinking fund shall be sufficient to fully provide for the payment of the principal of all such bonds and the full interest thereon to the date of their maturity, and the tax shall then be discontinued under the provisions of article seven, section eleven, of the constitution. The bill shall provide for a separate issue of the bonds of the state for each separate scheme of development and for the submission of the bill to a vote of the people for their approval at a general election as provided in article seven, section four, of the constitution for the creation of a debt.

§ 11. The commission shall have power to appoint such engineers, assistant engineers and experts, fitted by experience, to advise the commission and to conduct under its direction the surveys, and the preparation of plans, maps, calculations and estimates as may be necessary within any appropriation which may be available therefor.

§ 12. The general plan which shall be devised by the commission under the provisions of this act, shall not include any of the streams and water courses which supply the canals of the state, excepting such streams and water courses as the state engineer and surveyor and the canal board, shall state in writing, will not, if used as above provided, substantially diminish the water supply of such canals or the navigability thereof, and provided that such plan shall not include any development of water power which

would effect a diversion from any of the navigable waters of this state in sufficient quantity to interfere with the navigation of such rivers or water courses.

§ 13. The sum of thirty-five thousand dollars ($35,000), or so much thereof as may be necessary, is hereby appropriated out of any funds in the treasury of the state, not otherwise appropriated, to carry out the provisions of this act, and the said moneys shall be paid by the treasurer on the warrant of the comptroller to the order of the state water supply commission when certified by that commission to be needed from time to time in carrying out the provisions of this act.

§ 14. This act shall take effect immediately.

APPENDIX E.

CLASSIFIED STATEMENT OF EXPENDITURES UNDER CHAPTER 569, LAWS OF 1907, TO MARCH 1, 1908.

Appropriation.

July 12, 1907, by chapter 569, Laws of 1907.....		$35,000 00

Disbursements.

Compensation of Consulting Engineer.	$7,500 00	
Salaries of engineering force.....	13,508 53	
Maintenance expenses of engineering force	2,828 90	
Traveling and sundry expenses of Commissioners.	440 46	
Traveling and sundry expenses of Engineers.	1,170 79	
Digest of water laws.....	200 00	
Livery	1,137 33	
Engineering supplies	490 19	
Maps, blue prints and photographs...	173 46	
Rental and purchase of instruments..	461 38	
Test borings	1,663 20	
Stream gaging, in co-operation with U. S. G. S.....	1,754 86	
Rain gaging	428 93	
Printing and stationery	92 00	
Telegraph and telephone	99 65	
		31,949 68
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